RELATIVE TOXICITY OF SOME IMPARTIAL SYNTHETIC INSECTICIDES AND BIOCIDES TO CERTAIN PESTS

DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

Master of Philosophy

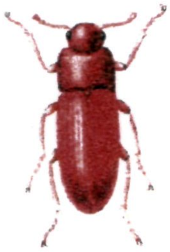
IN

ZOOLOGY

(ENTOMOLOGY)

By

Shashi Mala



DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2004

Dedicated

To my

Parents

DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH-202002
INDIA

Phones { External 2700920 21-345
{ Internal 3430

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2. FISHERY SCIENCE & AQUACULTURE
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Dated 20-4-05

CERTIFICATE

This is to certify that ***Miss Shashi Mala*** has carried out her research work entitled **"Relative toxicity of Some Impartial Synthetic Insecticides and Biocides to Certain Pests"**, under my supervision for the award of Master of Philosophy in Zoology (Applied Entomology) of this university.

She is therefore permitted to submit her findings for the award of M. Phil. Degree of Aligarh Muslim University, Aligarh.

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(PROF. ABSAR M. KHAN)

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Acknowledgements

I bow in deep reverence to Almighty God, the most beneficent and most merciful, whose benign blessings led me to complete this work and produce in its present form.

It is my privilege and gives me immense pleasure to express sound perception of gratitude, obeisance and esteem to my supervisor **Prof. Absar Mustafa Khan**, for his consistent encouragement, constructive suggestions and excellent supervision.

Delighted I feel to convey my sincere thanks to the Chairman **Prof. Mohammad Hayat** for providing necessary facilities and all my teachers for necessary cooperation and help as well.

I extend my thanks and gratitude to **Dr. R. Ahmad**, Principal Scientist (Entomology), Indian Institute of Pulses Research, Kanpur & **Dr. S.K. Singh** (Senior Scientist) IIPR, Kanpur, for their valuable suggestions.

I am also thankful to **Dr. M. Hafeez Khan, Musharraf A. Khan,** for their timely help and care.

I am indebted to Dr. Aayesha, for her precious and constructive suggestions and help in order to make this work success.

I wish to acknowledge my lab colleagues **Mr. Shah Mohd. Harish, Mr. Aslam Khan, Mr. Rashid Mumtaz Khan, Mrs. Tanu Sharma and Miss Ruqaiya Naqvi** for creating an ideal milieu to strengthen my thoughts and gain knowledge, my friends **Reshu, Mehdi and Anu** for their altruism and moral support throughout this study.

Finally with deep adoration I acknowledge my father for being my torch bearer, my mother for her unconditional love and never ending care and both of them for moulding me in to the person today I am.

I am thankful to my brother **Amit and** Sister **Reetu** for always making me feel that yes I can do it.

I am also thankful to **Abul Irfan** for typing the manuscript.

May I always get blessings of all of them who are mentioned above

Shashi Mala

Shashi Mala

Introduction

INTRODUCTION

The struggle between man and insects began long before the dawn of civilization and will continue as long as the human race. In addition to losses to crops in the field, insect come in way when the agricultural and other produce are stored. A number of insects including beetles and moths attack food grains in bins, mills, ware house, retail stores, godowns and in home. The damage done in this way is roughly estimated to run in to millions of rupees.

Food is the first and most important basic need of mankind. Since the world as a whole is in the grip of shortage of food, the preservation of food grain whatever is produced is of utmost importance. Problems of storage and that of distribution are satisfactorily solved. The problems of feeding hungry millions people with the substantial increase in food production.

The production of food grains in India has increased from 50.83 million tones in 1950–51 to 212.0 million tones during 2001–02 (Fertilizer statistics 1998–99, Economic Survey 2002–03).

Growing human population are finding it difficult to meet their food requirement and a sort of food crisis has developed in many developing countries like India. Food crisis can be met in two ways by increasing the production and by reducing the wastage in already produced grains. Therefore, food storage continue to be an important problem from the time man learn to grow crops and this problem is also a challenge to the scientists who are called upon to tackle it. These losses are merely in terms of quantity but also in quality of food grain. The qualitative losses are responsible for the chemical change is protein, carbohydrates, amino acids, fatty acids and vitamins. This will affect the nutritive value of the grain (Ghosh and Durbey 2003).

Girish *et al.* (1985) observed that about 25–40% of the grain produce is destroyed or consumed by different kind of pests at the pre and post harvest stages, it is tragic indeed that such large production never reaches the hungry human race worldwide. The annual post harvest losses caused by insect damage, microbial deterioration, improper storage practices and other factors are estimated to be 10–25% (Mathews 1993). The damage done in this way is estimated to run into millions of rupees. FAO (1984) reported that world wide annual losses of stored grains is 10% that is over 13 million tonnes.

In this context the 'war on waste' approach initiated in many countries needs to be speeded up with the improvement of safe storage as the first step in this direction.

Approximately one thousand species of insects have been found to be associated with stored products (Saxena 1995). Karnavar and Dalmini (1967) reported that beetles and moths predominates, from which the most common are *Rhizopertha dominica* (lesser grain borer), *Sitophilus oryzae* (rice weevil), *Tribolium castaneum* (rust red flour beetle), *Sitotroga cerealella* (grain moth), *Oryzaephilus* spp. (saw toothed beetle), *Callosobruchus chinensis* (pulse beetle), *Callosobruchus analis* (pulse beetle), *Lesioderma serricorne* (cigarette beetle), *Trogoderma granarium* (notorious dermested beetle).

The adoption of management practices is required right from the collection of grains from field as the *Sitotroga cerealella* Oliv. and *Sitophilus oryzae* Linn. are serious pests of maize in storage but the source of inoculation is through field infestation just prior to harvest (Singh *et al.* 1978; Rai and Singh 1979).

The lesser grain borer *Rhizopertha dominica* is important primary pest of whole cereal grains especially small grains such as wheat, sorghum, millet and rice throughout the world (Rees 1995). Both larvae and adults are able to attack whole sound grain (Elek 1994). The female of *Rhizopertha dominica* lays eggs on the surface of the wheat kernels and the first instar bore into the kernels after hatching. Female of *Sitophilus oryzae* oviposits directly into the kernel. The larvae of both species complete their development inside the kernel and emerge out as adults (Arthur 2003). Prevett (1959) reported that *R. dominica* posses 5–6 generations in one year and they hibernate during the period of December to February.

Tribolium castaneum, commonly known as red flour beetle, attacks a large variety of stored commodities. It has been shown that grains are quite immune to this insect but they constitute a very favourable developmental medium. A newly hatched larva is unable to penetrate into sound grains which if damaged by other borers, support the development of this insect by permitting an easy access to these larvae inside the grain (Singh *et al.* 2001).

Callosobruchus spp. are the most common stored grain pest of pulses. The pest is cosmopolitan and its degree of damage depends upon the humidity, temperature and abundance of food material in the stores (godowns). Gupta *et al.* (1981) reported that *Callosobruchus chinensis* alone causes around 55.20% loss to chickpea.

There are several factors worked out by different workers which affect insect infestation in stored grains. Coghurn (1974) and Rout *et al.* (1976) reported negative effect of grain hardness on the insect infestation. Katiyar and Khare (1983) stated that initial moisture content of seed was significantly correlated with different growth parameters. Ram *et al.* (1996) observed positive correlation between grain size and mean number of progeny adult emergence and concluded that increase in size was associated with corresponding increase in weevil susceptibility of the grains. Grain size has been reported to affect ovipositional response of weevil (*Sitophilus* spp.) in various cereals and millets, the larger grains receiving more eggs than smaller ones.

Howe and Currie (1964) observed that 32.5°C temperature and 90% relative humidity was most ideal condition for proper development and at 37.5°C the pest can not complete its life cycle but it can develop at 17.5°C temperature. Yadav (1993) reported that *Rhizopertha dominica* can survive at minimum seed moisture content of 9.0–10.0% while optimum survival is at 11.0–14.0%.

By keeping in mind the biology of insects and losses caused by them, appropriate management strategies are required to be adopted. Introduction of insecticides has revolutionized the protection technology. With the help of insecticides most of the insect population is managed effectively in a very short period (Guedes 1990). In our country the consumption of synthetic organic pesticides has led to important role in increasing food production (Arthur 2003). The high specific toxicity against the target pest should not affect the rest of ecosystem so that natural parasites, predators and other beneficial insects are unharmed (Spollen and Insman 1996).

Insecticide resistance problem is growing fast involving more and newer insecticides. Almost all commonly known insecticides have developed resistance against different stored grain pests (Srivastava *et al.* 2001). Resistance can be broken by using different insecticides during storages as Kang. and Chawla (2000) observed that malathion resistance in *T. castaneum* did not extend to other organophosphorus and synthetic pyrethroid insecticides tests, these results revealed that protective mechanism developed in this strain against malathion were not operative against other insecticides and resistance in the test strains was specific type as it did not extend to organophophorous insecticide unrelated in structure to malathion. Pradhan and Bhatia (1956) conducted experiments to find toxicity of synthetic contact insecticides against *Tribolium castaneum* Herbst. and found that DDT was effective against red flour beetle.

For the effective control of stored grain pests preventive and curative measures have been recommended. Among these methods, fumigation is widely practiced because fumigants are cost effective, efficient, practical, quick and easy to use. For the control of *Rhizopertha dominica* phosphine (celphon, phostoxin, quickphos etc.) has been found to be the most effective fumigant (Lindgren and Vincent 1966, Hole *et al.* 1976, Price and Mills 1988)

The emergence of resistance to fumigants in stored product pests is a matter of serious concern in recent years. The FAO global survey report shows that fumigant resistant strains are now prevalent in many countries. Out of 489 strains tested 82 showed resistance to 3 species viz. *Sitophilus oryzae, Tribolium castaneum* and *Rhizopertha dominica* (Champ and Dyte 1976).

Yadav *et al.* (1983) observed that organophosphorus insecticides possess a broad spectrum effectiveness against stored grain pests. *Stegobium panicum* and *Tribolium castaneum, Rhizopertha dominica, Sitophilus oryzae, Callosobruchus* spp. are the most and least susceptible species when tested for organophosphorus insecticides with low mammalian toxicity.

Ajri *et al.* (1986) and Patil *et al.* (1986) pointed out that the introduction of synthetic methyl parathion, monocrotophos and cypermethrin brought desired effects in control of stored product pests. Lata and Singh (2004) investigated combined effect of temperature and relative humidity on *C. chinensis* and 30±1°C temperature with 5% RH found most deleterious while using pyrethroids.

Johnson (1990) reported that while using insecticides against stored grain pests, there may be some toxicological benefits of combination treatments although any such effects may depend on the specific insecticide because organophosphates generally have positive correlation with temperature, their toxicity increases with increase in temperature while toxicity of most pyrethroids decreases with increase in temperature.

Jaiswal and Patil (1990) applied dimethoate and monocrotophos against *Heliothis armigera* and found that 0.03% dimethoate and 0.04% monocrotophos were equally effective to control the pest. Pillai *et al.* (2004) conducted experiments to test the efficiency of fungicides against stored grain pests. Thiram and Bavistin were found equally effective to monocrotophos and BHC to reduce dead hearts caused by *T. castaneum* and *R. dominica.*

Singh *et al.* (1995) conducted experiments to see the efficacy of different organophosphates and observed that chlorpyriphos–methyl caused complete kill to *Sitophilus oryzae* on polypropylene, polyethylene and aluminium surfaces. On jute and poly propylene surfaces kill was 93.3% against *S. oryzae* and 80–90% against *T. granarium* persistency declined after 6 months.

Over conventional insecticides, recently originated synthetic pyrethroids are more effective. These are more photostable as compared to natural pyrethrins and other insecticides. Their use in protection of various crops against insect pests is increasing day by day because of quick knock down action, and requirement of their very low quantity to manage stored grain pests is additional benefit, these are required for spray over crops hence environmental contamination and pollution is very low. Gupta *et al.* (1992) found cypermethrin effective against *Callosobruchus chinensis* while using it as seed protectant at

100 ppm dose up to 120 days. Verma *et al.* (1988) reported that cypermethrin and methyl parathion were toxic against *Anomala dimdiata* a polyphagous beetle.

Saxena *et al.* (1995) recommended requirement of serious consideration on the use of the potent synthetic pyrethroids against prevailing lindane and phosphine resistant population as cypermethrin and dimethoate showed resistance to lindane and DDT resistant strains of *Tribolium castaneum*.

The United Nation Environmental Programme (UNEP) reports that three hundred species have developed resistance by continuous and indiscriminate use of same pesticides which were found effective to control them (Sanders 1982).

Insecticides have been in use to combat the insect menace. However, their indiscriminate use has resulted in adverse effects like resistance (Saxena *et al.* 1992) and resurgence of secondary pests, (Narasaiah 1994). In addition, environmental pollution and an alarming increase in the cost of pesticides have made the need for effective and biodegradable pest control material with greater selectivity.

As regard to the stored grain due to the awareness of health hazards and residual effects of chemical insecticides, there is a demand for safer insecticides. Thus, synthetic chemical insecticides can be replaced for stored product protection which is highly desirable. The selection of appropriate botanical methods may become compatible with various compound of stored product protection as developing countries are promising for ecological safe farming.

The development of alternative plant protection technology based on plant extracts now become applicable among them when product have been found effective against wide range of pest of important crop (Schmutterer *et al.* 1995). The plant products have been used as grain protectant against stored grain pest for minimizing the storage losses information regarding the medicinal properties of large number of plants was available. Plant materials such as pyrethrum, rotenone and nicotine were among the first compounds used to control agricultural pest (Grange and Ahmad 1988). Recently some attempts have been made by various workers in different parts of the world showing that indigenous plant products are used as grain protectants against insect pests in stored grains to minimize the storage losses, due to insects (Xie *et al.* 1995).

A variety of higher plants may prove to be a new source of natural pesticides (Grainge and Ahmad 1988, Arnason *et al.* 1989). Many higher plants contain essential oils (Guenther 1948). These oils and their constituents have been shown to be a potent source of botanical pesticides (Singh and Upadhyay 1993). Their activities are manifold and they induce fumigant and topical toxicity as well as antifeedent or repellent effects (Regnault and Roger 1997). Among these, various spices used traditionally for protecting foodstuffs against insects. The popular household use of these spices as insect repellents for preserving food grain has led to experimental evaluation of them for possible use as pesticides. It is a popular practice to use potpourri, cloves, oranges and other spices and herb bags to scent the rooms and cupboards and to keep out moths and other insects (Norman 1990). Therefore, screening of such type of plants for antifeedent activity is important in discovering safe, biodegradable and alternative to synthetic insecticides. Recently, special efforts have been made to screen plant extracts for their antifeedant activity in laboratory (Doss *et al.* 1980).

Most researches have revealed that plant products disrupt normal development of insects. Kumari and Kumar (1994) gave the mechanism of action of plant products which interfere with the general physiology of insect pests. They observed that some of the botanical pesticides interfere with the steroid utilization in insect pests such as *Spodoptra* sp., *Heliothis* sp. and locusts. Ayyangar and Rao (1989) reported that methanol and hexane extracts of neem seed kernels are not only larval repellent but also ovipositional deterrents to *Spodoptra litura.* Ahuja and Sehgal (1982) revealed the presence of glucosinolates and isothiocynates in mustered oil, and isothiocynate is known to posses insecticidal property.

The insecticidal property of alkaloids and nicotine have been known since 1800 (Metcalf *et al.* 1962, Ware 1986). The available information on pyrethrins, rotenone and nicotine shows that these insecticides of plant origin are completely safer to mammals as well as other animals (Feninstein 1952).

Recently, the plant products are being used as grain protectants against insect pests in stored grains to minimize the storage losses caused by insects (Annapurna *et al.* 1984, Bell *et al.* 1990, weaver *et al.* 1991, Xie *et al.* 1995). Coating of seeds with vegetable oils has already proved their effectiveness in controlling the *Callosobruchus chinensis* (Jacob 1994a, Parasai *et al.* 1994).

Among several options *Azadirachta indica* (neem) has evoked a great deal of intrest because of its bioefficacy and biodegradability. The compound mainly responsible for toxic effect that was first identified by Zanno *et al.* (1975) and named Azadirachtin. It is a tetranotriterpenoid (Butterworth and Morgan 1968). It acts both as antifeedent and as an interfering agent with growth, development and reproduction of insects. The developmental aberration caused by Azadirachtin in several of immature insects has been shown to be associated with significant reduction or delay in normal moulting hormone fraction (Garcia *et al* 1986, Borrn *et. al.* 1986).

Neem leaf powder @ 5% giving protection to stored cowpea against *Callosobruchus chinensis* was reported by Jacob (1994b). Sharma (1983) reported 32.6% reduction in weight loss due to treatment of the maize grains by neem leaf powder @ 10:100 against *Rhizopertha dominica.* Singh and Sharma (1995) tested neem oil against *Callosobruchus chinensis* @ 10ml/kg seed where no egg laying had taken place. Moreover the average number of eggs laid in untreated contrcl was 63.33 per 50 seeds.

Jotwani and Sircar (1965) observed that the powdered neem seed kernel when mixed with wheat seeds @ 1–2 parts per 100 parts of seeds was effective to protect wheat seeds against *Sitophilus oryzae, Rhizopertha dominica* and *Trogoderma granarium* for at least about 269, 321 and 379 days respectively. Neem seed powder has also been reported to be effective in controlling *Tribolium castaneum* and C*allosobruchus analis* (Pandey *et al.* 1986, Yadav and Bhatnagar 1987, Zehnder and Warthen 1988, Jilani and Saxena 1990). Jacob *et al.* (1993) studied the effect of leaf powder of plants namely *Datura alba, Calotropis procera, Azadirachta indica* and *Eucalyptus sp.* against adults of *R. dominica*. Sharma (1983) reported the antifeedent property of *C. procera* against *R. Dominica.*

Sahayaraj and Paulraj (2002) observed that *A. indica* leaf extract was found to be the most effective repellent against *T. castaneum* on groundnut seed. Followed by those of *Vitex regundo,* onion and *Calotropis procera.* Yogita and Singh (2001) applied plant extracts viz. Neem (*Azadirachta indica*), arandi (*Ricinus cummunis*), karan'z (*Deris indica*) and datura (*Datura metel*) @ 1.0, 2.5 and 5.0 ml/100 gm of seeds of sorghum and they were found to be oviposition deterrent against *T. castaneum*.

Yadav and Bhatnagar (1987) indicated the effects of dhatura leaf powder and neem leaf powder in the stored cowpea seed for protection from *Callosobruchus chinensis*, variation in number of adults emerged in rice grains treated with different plant parts may be due to their adverse effects on the fecundity and of different developmental stages of *R. dominica*.

Mishra (1999) reported moderate seed weight loss i.e. 8.83% after mixing *Lantana* sp. leaf powder with grains against *Callosobruchus chinensis* but seeds were found partially damaged at 150 days of confinement of the bruchids. Singh *et al.* (1996) used 3% of *Lantana camara* extract against *R. dominica* which resulted in lower fecundity per female and adult emergence, a prolonged duration for completion of one generation proved most effective in terms of adult mortality and also reduced grain damage effectively. Tripathi *et al.*

(2001) reported effect of 20% w/v ethanolic extract on *Callosobruchus chinensis* Linn.

From time immemorial, efforts have been made to overcome the stored grain losses. Keeping in view the safety of stored products and environment, there is a great need for investigation of pesticidal chemicals with reference to toxicity, efficacy and hazards. Plant origin pesticides now called biocides, on the whole are supposed to be ecofriendly and fulfilling the requirement of present day agriculture.

The present investigations were carried out for bioefficacy test of biocides as well as synthetic pesticides and to compare their effectiveness. Four stored grain pests were selected on the basis of their occurrence in the north Indian agricultural products. These insects are *Sitophilus oryzae* (L.) *Callosobruchus chinensis* (L.), *Tribolium castaneum* (Hubner), *Rhizopertha dominica* (F.).

Materials and Methods

MATERIALS & METHODS

1. Breeding and maintenance of stock culture:

A survey was conducted at the different farm houses godown and mandees of the Aligarh. Different stored grain pests were collected from these places of survey. These pests were brought to the laboratory and identified as *Tribolium castaneum* (Herb.), *Rhizopertha dominica* (Fab.), *Sitophilus oryzae*(Linn.) and *Callosobruchus chinensis* (Linn.) by the taxonomist at department of zoology, AMU, Aligarh. The culture of *Tribolium castaneum* and *Rhizopertha dominica* were maintained by rearing them on sterilized and conditioned wheat flour and wheat grain respectively, while the culture of *Callosobruchus chinensis* was maintained by rearing it on sterilized and conditioned Moong and lobia grains and *Sitophilus oryzae* on rice grains. Glass rearing jar of the size 15cm diameter and 25 cm height and muslin cloth were sterilized by exposing them to ultra violet light in the laminar flow for 15 minutes.

In each rearing jar sterilized and conditioned wheat/lobia/moong/rice grains were taken and about 20 pairs of one day old adults of *Tribolium castaneum, Rhizopertha dominica, Sitophilus oryzae* and *Callosobruchus chinensis* were released separately in each jar for oviposition. These jars were then covered by muslin cloth using rubber bands. After a week's time adults were sieved out and released in a fresh sterilized jar containing. Wheat/lobia/gram/moong/rice grains. Rearing of these insects was done at temperature 28±1°C and relative humidity 75±5%. A succession of such Jars was maintained to ensure constant and ample supply of insects of uniform age and stage for experimental work. One day old adults were used for experiments.

Those factors which directly influence rapid multiplication of insect are temperature and humidity and thus in the present investigation temperature and humidity were maintained during the investigation Insects were handled with care to avoid any mechanical and physical injury in order to prevent any microbial infection, because Fungi, play an important role in detoriation of grain while in the insectory.

2. Preparation of Insecticides:

Cypermethrin (25% EC), Dimethoate (30% E.C.), Monocrotophos (36% SL), Chlorpyriphos (20% E.C.), Methyl Parathion (50% E.C.).

Insecticides were obtained from the manufacturers for experimental purpose. Technical insecticides were diluted to 2% stock solution using double distilled water by Pearson's square method and were refrigerated until needed.

3. Preparation of Biopesticides:

The four different plants namely *Azadirachta indica* (leaves and seeds) *Datura fastuosa* (leaves), *Calotropis procera* (leaves) and *Lantana camara* (leaves) were collected from the university campus A.M.U. Aligarh. This plant material were washed thoroughly in double distilled water and then shade dried. Fine powder was made by grinding the dried leaves, and seeds of *Azadirachta indica* and leaves of *Datura fastuosa, Calotropis procera* and *Lantana camara.* 100 g powder of each of the above was mixed with 100 ml of alcohol separately. The mixture was left overnight for defatening and extraction of the required material. It was filtered using Whatman filter paper No.2 and then the residue so obtained was again subjected to the same treatment as above.

The final filterate was treated with 200 ml of methanol (90%) for one hour the process was repeated twice. The solution of filterate and methanol (90%) was left for evaporation on water bath at temperature 47 ± 2 °C. The residue left after evaporation was mixed with 200 ml of ethyl acetate and water in the ratio 1:1 v/v. The Ethyl Acetate Fraction (EAF) was obtained and was later washed with water twice to discard water soluble products. EAF and water were mixed thoroughly and then the solution was left to rest till the visibility of two clear layers of EAF and water, the water layer was drained out by separating funnel

Diagrammatic representation of plant material extract:

Fine powder (100 gm.)
+
Alcohol (100 ml)
↓ over night for Defatening and Extraction

Residue
+
Alcohol (100 ml)
↓ Filter
Residue Discarded

Filtrate + Methanol 90% (200ml twice)
↓ 1hr.
Evaporate (47 ± 2°C)
↓
Residue + Ethyl Acetate : Water (1:1 v/v) 200 ml
↓
Ethyl Acetate fraction (EAF) washed twice with water
↓
EAF + Sodium Sulphate (5 gm)
↓ Filter
Filterate evaporated to dryness (47 ± 2°C)
↓
Residue + Carbon tetrachloride (100 ml)
↓ Kept at 0±4°C
Crystals

and 5gms of anhydrous Sodium Sulphate was added to the thoroughly washed fraction of Ethyl Acetate to absorb the moisture content. The residue was mixed with carbon tetrachloride (100 ml) and was kept at $0 \pm 4°C$ to get crystals.

The Pearson's square method was adopted to prepare 2% stock solution from crystals which were considered technically 100% pure. The stock solution was kept at 4°C and further concentrations were made as per experimental requirements.

4. Insecticide bioassay:

Small pellets of wheat flour, gram flour and rice flour (approximately of the same weight) were prepared and dried at temperature $32 \pm 1°C$. From the stock solution of both chemical and botanical insecticides further dilution viz. 0.005%, 0.01%, 0.025% 0.05%, 0.1%, 0.25%, 0.5%, 1.0% were made. Five dried pellets were dipped in each concentration of the each insecticide and biopesticide for 20 minutes. Pellets were carefully taken out and again dried at temperature $34 \pm 1°C$. The toxicity was tested in 100 mm petriplates. Petriplates were sterilized and in each petriplate five treated flour pellets were placed and 50 one day old adults of the experimental stored pests were released. Petriplates were closed with their lids. The experiment was set in controlled temperature and humidity. For each concentration, three replicates were maintained for testing effect of each concentration on samples of stored grain pests. Insects were examined individually by the naked eye and also under stereo microscope whenever needed. Mortality was determined up to 48 hours after treatment. Insects were considered dead if no movement was observed when the snout was pinched with forceps. Observations were taken at every 24 hour interval and data was subjected for statistical analysis.

5. Statistical analysis:

Following statistical methods were used to the results of the present findings:

5.1 Arithmetic Mean:

$$\overline{X} = \frac{\Sigma X}{N}$$

where ΣX = sum of observations ($X_1 \ldots\ldots X_n$)

N = Number of observations.

5.2 Standard deviations:

$$SD = \sqrt{\frac{ED_x^2}{N-1}}$$

where

$$d^2 X = (X - \overline{X})^2$$

$\bar{X}$ = mean of all observation

N = Number of observations.

5.3 Chi–square test (x^2):

χ^2 for heterogeneity was applied to resolve the discrepancy between the obtained observed and expected frequencies:

Following x^2 give formula was used

$$\chi^2 = \Sigma \frac{(F_0 - F_e)^2}{F_e}$$

where

F_0 = observed frequency

F_e = Expected frequency

5.4 Linear Regression equations:

The coefficient of liner regression β (slope) was calculated by using the following equations:

$$\beta = \frac{\Delta y}{\Delta x} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

where

Δy = change in value of y

Δx = change in value of x

Y = a+bx.

The equation was applied to draw the regression lines of the data, obtained from different chemical/botanical insecticides respectively.

5.5 Coefficient of Correlation (r):

To set a relationship between the applied concentration of pesticide and Biopesticides the mortality of the insects (Pests).

Pearson's coefficient of correlation (r) was the calculated by the following formula:

$$r = \frac{\Sigma x_i \ Y_i}{n\sigma_x\sigma_y}$$

where

x_i = concentrations applied

y_i = Percent mortality recorded the respective treatment

n = Number of observations.

σ_x and σ_y = standard deviation of x and y variables.

5.6 Lethal concentration (Lc_{50}):

LC_{50} values were calculated from the transformed mortality concentration graphs.

5.7 Relative ratio/Relative toxicity:

Relative toxicities for each chemical insecticide and biopesticides for LC_{50} values were calculated by taking the highest LC_{50} as using and dividing it by LC_{50} as unity and dividing it by LC_{50} from the same vertical column.

Figures

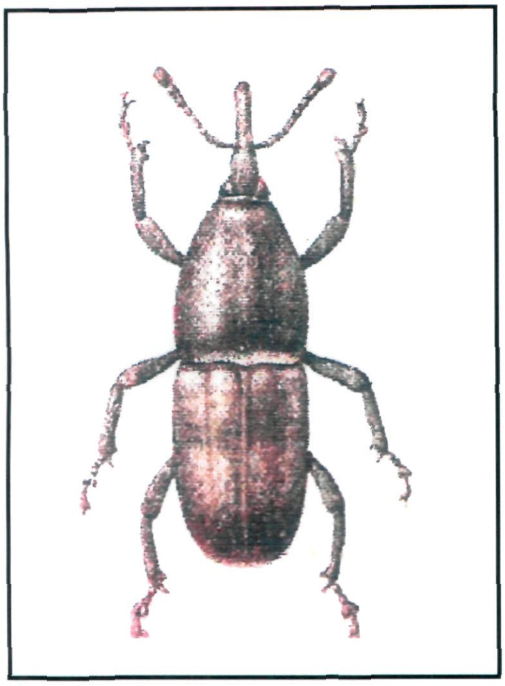

Fig. 1: *Sitophilus oryzae* (Adult)

Fig. 2: *Callosobruchus chinensis* (Adult)

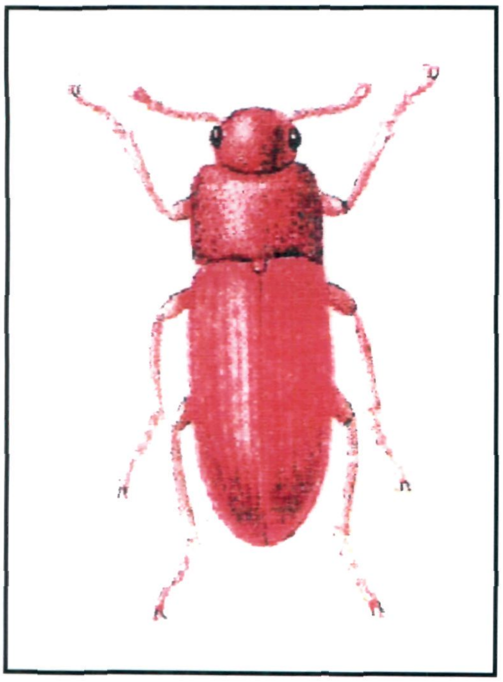

Fig. 3: *Tribolium castaneum* (Adult)

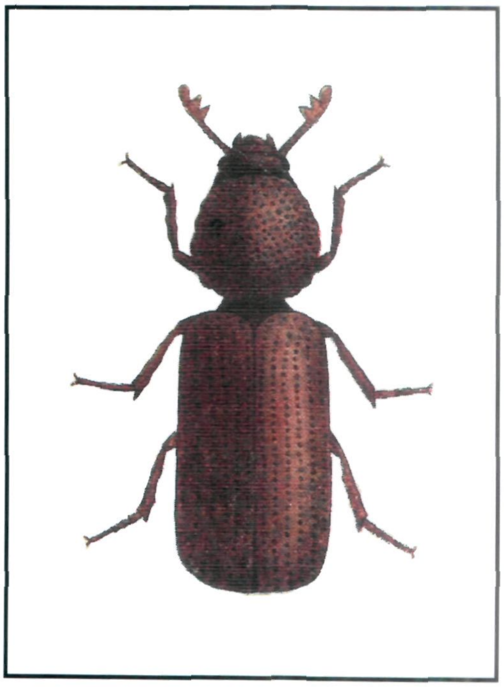

Fig. 4: *Rhizopertha dominica* (Adult)

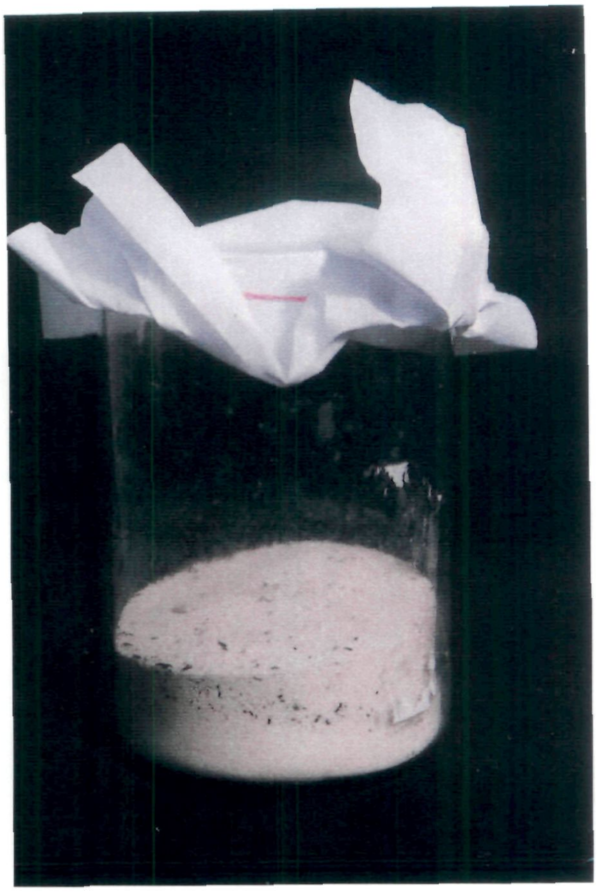

Fig. 5: Mass culture of *Rhizopertha dominica*

Fig. 6: *Rhizopertha dominica* infesting suji

Fig. 7: Mass culture of *Sitophilus oryzae*

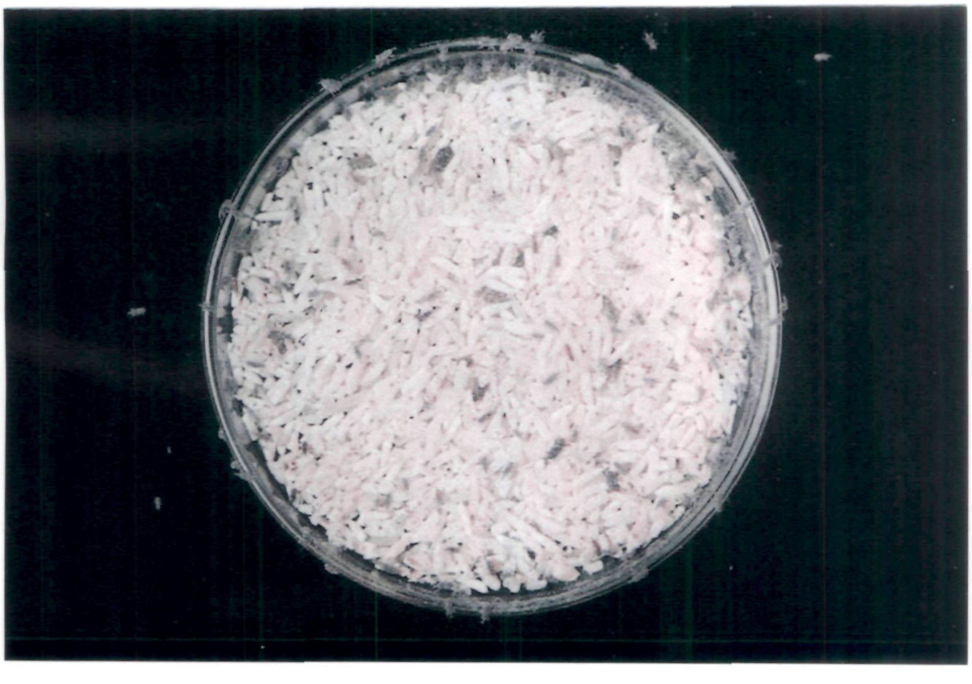

Fig. 8: *Sitophilus oryzae* infesting rice grains

Fig. 9: Mass culture of *Tribolium castaneum*

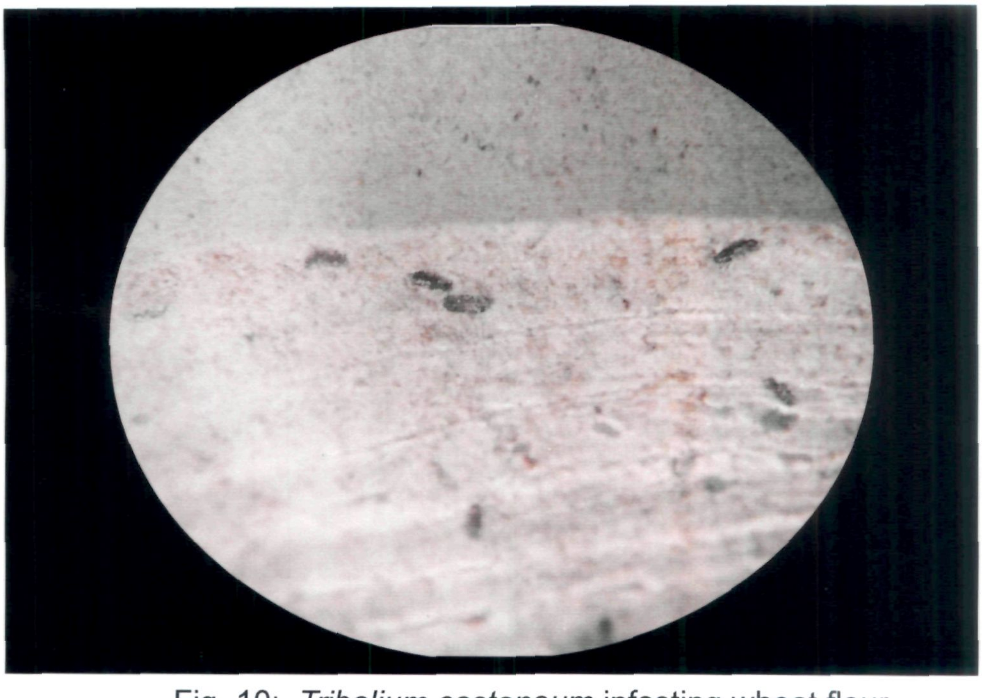

Fig. 10: *Tribolium castaneum* infesting wheat flour

Fig. 11: Mass culture of *Callosobruchus chinensis*

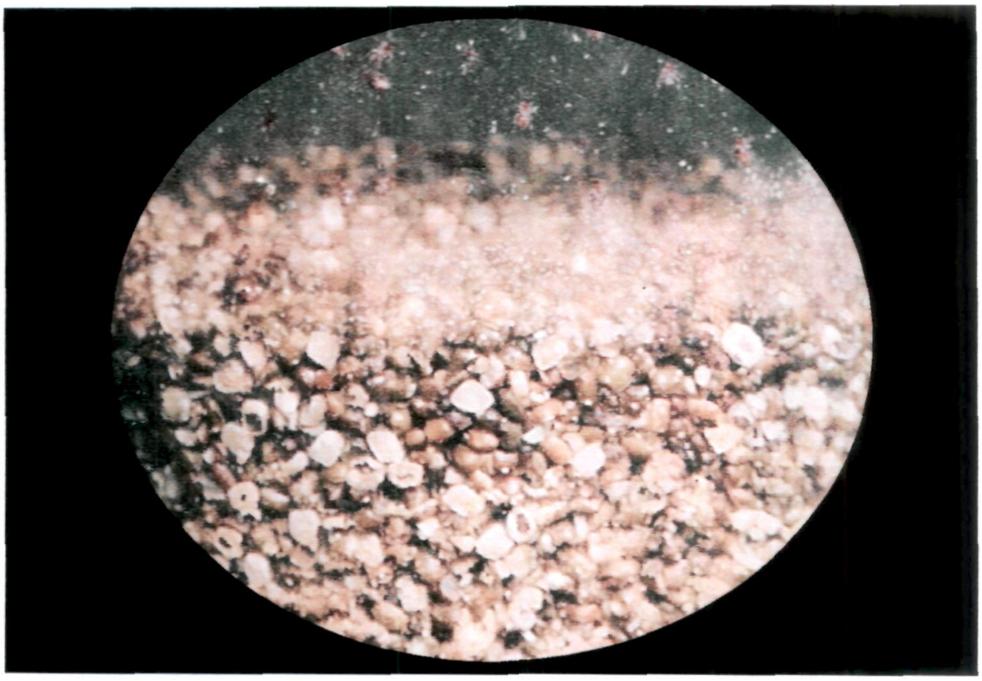

Fig. 12: *Callosobruchus chinensis* infesting mung grains

Results

RESULTS

A survey was conducted in the different farm houses, godowns and mandees of Aligarh for the collection of stored grain pests. These insects were brought to the laboratory, for identification and for further study. The relative toxicity of five synthetic insecticides *viz.* Monocrotophos, Methyl parathion, Dimethoate, Chloripyrifos, Cypermethrin and five Biocides *viz. Azadirachta indica* seed extract. *Azadirachta indica* leaf extract, *Calotropis procera* leaf extract, *Datura fastuosa* leaf extract and *Lantana camara* leaf extract on four stored grain pests namely *Rhizopertha dominica, Callosobruchus chinensis, Sitophilus oryzae* and *Tribolium castaneum* was assessed in laboratory under controlled conditions.

(1) *Rhizopertha dominica* (Fab.)

Rhizopertha dominica commonly known as "lesser grain borer", is a pest of wheat, rice, maize, jowar, barley, dried fruits etc. It is cosmopolitan in nature and mostly found in India, Pakistan, America, Argentina, Australia etc. Both larvae and adults cause damage. The adult is a small cylindrical beetle measuring about 3 mm in length and less than 1 mm in width. The larvae is about 3 mm long, dirty white, with a light brown head and a constricted elongated body. The pest breeds from March to December. A single female can lay 300-400 eggs. The eggs are white and cylindrical. The development from egg to adult requires approximately 28±2°C. The larval and pupal stages are passed with in the grain or in the grain dust. The adults and grubs cause serious damage to the grains by feeding inside them and reducing them to mere shells with many irregular holes.

(2) *Sitophilus oryzae* (Linn.)

Sitophilus oryzae commonly known as "Rice weevil" is cosmopolitan in distribution and is found throughout the India. This is the most common and perhaps the most destructive insect pest of stored grains throughout the world. Both adults and grubs cause damage. The adult is a small reddish-brown beetle about 3 mm in length with a cylindrical body and a long slender, curved rostrum. Its elytra bears four light reddish or yellowish spots and thorax is fitted with round depression. The life cycle is completed in 36-50 days and 5-6 generations are found in a year. It is observed that each female lays 300-400 eggs on grain. The eggs hatch in 6-7 days and the young larvae bore into grain. Heavy damage may be caused by this pest to wheat, rice, maize and sorghum grains particularly in monsoon.

(3) *Tribolium castaneum* (Herb.)

Tribolium castaneum is commonly known as "rust-red flour beetle". The insect does not cause damage to whole grain but mainly feeds on broken or attacked grain by other insects. The insect is specially harmful to flour, maida and suji. It is small radish brown beetle measuring 3.5 mm in length and 1.2 mm in width. The life cycle is completed in 38-114 days at 28±2°C. Many generations are found in a year. In the present study it is observed that the single female of *Tribolium castaneum* lays nearly 450-500, white, transparent and cylindrical eggs in the flour. In severe infestation it is observed that the flour turns from white to grayish and mouldy and has a pungent and undesirable odour, making it unfit for human consumption.

(4) *Callosobruchus chinensis* (Linn.)

Callosobruchus chinensis is commonly known as the "Gram dhora" (pulse beetle). It is a notorious pest of arhar, mung, urd, pea, gram, lentil, cowpea, soyabean, beans and other leguminous seeds. It is widely distributed in tropical and subtropical countries. The pest breeds actively from March to the end of November. It hibernates in winter in the larval stage. A single female of *Callosobruchus chinensis* lay 34-113 eggs at the rate of 1- 37 per day at temperature 28 ± 1°C. The eggs are whitish, small, oval, cemented to the grain. Adults are medium sized measuring 3.5 to 4.0 mm. The white larvae which later acquires creamy hue bore in to the grain and complete its development. Damage is at peak from April to September and is considerably reduced in October–November. The larvae and adults both cause severe infestation which turns the grain unfit for human consumption.

Toxicity of different insecticides and biocides against four stored grain pests:

Toxicity of five chemical insecticides *viz.* Monocrotophos, Methyl parathion, Dimethoate, Cypermethrin, Chlorpyrifos and botanical insecticides *viz. Azadirachta indica* leaf extract, *A. indica* seed extract, *Calotropis procera* leaf extract, *Datura fastuosa* leaf extract and *Lantana camara* leaf extract was determined against the one day old adults of four stored grain pests at 48 hour exposure. Mortality is low at 24 hour at the highest (1%) concentration so the further continuation of the observations is required and two experimental pests *Sitophilus oryzae* and *Callosobruchus chinensis* gave 100% mortality at 1% conc. at 48 hour, for the significance of relation between time interval and concentration results formulated at 24 hour exposure are also presented but summary data is presented for 48 hour only because at 24 hours the data calculated could not present a clear picture of mortality responses. The tables 1-12 and Fig. 1-20 show the detail analysis of heterogeneity test (x^2), linear regression, lethal concentration (LC_{50}), relative ratios and comparative toxicity of all respective chemical and botanical insecticides against *Rhizopertha dominica, Sitophilus oryzae, Tribolium castaneum, Callosobruchus chinensis.* The detailed results are as follows:

1. Synthetic insecticides:

1.1 *Rhizopertha dominica*

1.1.1 Efficacy:

The experimental results show that when *R. dominica* adults are fed on pellets treated with monocrotophos, methyl parathion, dimethoate, cypermethrin and chlorpyrifos at 24 hour exposure, monocrotophos gave highest 37.00% mortality and lowest mortality was recorded in case of chlorpyrifos at 1% concentration. Whereas at 48 hours monocrotophos at 1% concentration resulted in highest mortality i.e. 88.00% and lowest 73.00% by Chlorpyrifos (Table 2).

1.1.2 Chi square (x^2) test:

All the toxicity responses were heterogenous with insignificant x^2 values as inferred from the x^2 test, except for methyl parathion (14.38) and dimethoate (15.84) significant at $P < 0.05$.

The simple linear regression significance test show that all slope factors for the respective synthetic insecticides formulation responses are significantly different ($df=7$, $p<0.05$) against *R. dominica*. (Table...).

1.1.3 Lethal concentration:

LC_{50} values were calculated. The lowest and highest LC_{50} values were 0.0887% and 0.2925% for monocrotophos and chlorpyrifos respectively at 48 hours proving them most and least toxic (Table 3).

1.1.4 Coefficient of correlation:

A significant positive linear correlation (r=0.91) for chlorpyrifos and a least value (r=0.86) for monocrotophos is noted. (Table 3).

1.1.5 Order of toxicity:

The experimental results show that monocrotophos is the most effective and chlorpyrifos is the least effective. The order of toxicity is monocrotophos > cypermethrin > methyl parathion > dimethoate > chloropyrifos. (Table 2)

1.2 *Sitophilus oryzae*:

1.2.1 Efficacy:

When *S. oryzae* adults are allowed to feed on treated pellets with different concentrations of monocrotophos, at 1% concentration 100% mortality was obtained, while at the lowest i.e. 0.005% conc. of monocrotophos, mortality attained was only 8.00%. Chlorpyrifos proved to be least effective as compare to other chemicals. It resulted in 79.33% mortality at 1% conc. at 48 hour while at 0.005% conc. it caused 7.00% mortality which is close to that caused by monocrotophos (Table 5).

1.2.2 Chi square (x^2) test:

The toxicity responses of monocrotophos, cypermethrin and dimethoate gave insignificant x^2 values while methyl parathion (16.77) and chlorphyrifos (14.78) was significant at $P < 0.05$.

In the simple linear regression analysis it is found that there is straight line relationship and all the slope factors have significant difference in all the respective insecticides ($df=7$, $p<0.05$) (Table 6).

1.2.3 Lethal concentration:

The LC_{50} values of all the chemical insecticides used in the present study are calculated. The highest LC_{50} is calculated for chlorpyrifos (0.2230) and lowest in case of monocrotophos (0.0750) (Table 6).

1.2.4 Coefficient of correlation:

A significant positive linear correlation ($r=0.90$) was recorded for monocrotophos, dimethoate and chlorpyrifos and lowest ($r=0.87$) is recorded for cypermethrin (Table 6).

1.2.5 Order of toxicity:

The experimental results obtained show that monocrotophos is the most effective and chlorpyrifos the least effective treatment out of all chemical insecticides used. The order of toxicity is monocrotophos > cypermethrin > methyl parathion > dimethoate > chlorpyrifos. (Table 5)

1.3 *Tribolium castaneum*:

1.3.1 Efficacy:

Observations made on *T. castaneum* feeding on treated pellets show that insects obtained highest mortality i.e. 90.33% at 1% conc. for monocrotophos at 48 hours, while chlorpyrifos and dimethoate gave lowest mortality 78.00% and 77.66% respectively (Table 8).

1.3.2 Chi square (x^2) test:

The toxicity responses of methyl parathion (15.77) and chlorpyriphos (16.83) are significantly heterogeneous ($P<0.05$). x^2 values of monocrotophos, dimethoate, and cypermethrin were insignificant as is inferred from chi square (x^2) test.

In the simple linear regression analysis it is found that all the slope factors are highly significant for the respective insecticides. ($df=7$, $p < 0.05$) (Table 9).

1.3.3 Lethal concentration:

LC_{50} values calculated for all the chemicals used against *T. castaneum* shows that lowest (0.0930) and highest (0.240) are obtained for monocrotophos and cypermethrin respectively (Table 9).

1.3.4 Coefficient of correlation:

A significant positive linear correlation ($r=0.90$) for chlorpyrifos and lowest ($r=0.87$) for monocrotophos was recorded (Table 9).

1.3.5 Order of toxicity:

The highest and lowest toxicity determined are that of monocrotophos and chlorpyrifos respectively. The order of toxicity is monocrotophos > cypermethrin > methyl prathion > chlorpyrifos > dimethoate (Table 8).

1.4 *Callosobruchus chinensis*:

1.4.1 Efficacy:

The observations made on the comparative responses of *C. chinensis* adults which are allowed to feed on treated pellets indicate that highest mortality reaches to 100% at 1% monocrotophos and cypermethrin at 48 hour exposure, followed by methyl parathion (88.00%), dimethoate (80.66%) and chlorpyrifos (78.66%) (Table 11).

1.4.2 Chi square (x^2) test:

The calculation of x^2 test show that value corresponding to mortality responses of cypermethrin (15.67) was significant at df = 7, P <0.05. x^2 values of methyl parathion, demethoate and chlorpyrifos were insufficiently heterogeneous.

In the simple linear regression analysis it is found that all the slope factors are highly significant of the respective insecticides. Significance levels are highest for cypermethrin and chlorpyrifos (df=7 and p < 0.05) (Table 12).

1.4.3 Lethal concentration:

LC_{50} values were calculated for all the insecticides. The lowest and highest LC_{50} values for monocrotophos and chlorpyrifos are 0.0760 and 0.2375 respectively (Table 12)

1.4.4 Coefficient of correlation:

A significant positive linear correlation (r=0.91) is noted for cypermethrin and a least value (r=0.83) is obtained for dimethoate in case of *T. castaneum* (Table 12).

1.4.5 Order of toxicity:

The highest and lowest toxicity determined are that of monocrotophos and cypermethrin. The order of toxicity is monocrotophos > cypermethrin > methyl parathion > dimethoate > Chlorpyrifos (Table 11).

1.5. Comparative efficacy to the four pests:

1.5.1. Monocrotophos:

C. chinensis > S. oryzae > T. castaneum > R. dominica.

1.5.2. Methyl parathion:

C. chinensis > S. oryzae > T. castaneum > R. dominica.

1.5.3 Dimethoate:

S. oryzae > C. chinensis > R. dominica > T. castaneum.

1.5.4 Cypermethrin:

C. chinensis > *S. oryzae* > *T. castaneum* > *R. dominica.*

1.5.5 Chlorpyrifos:

S. oryzae > *C. chinensis* > *R. dominica* > *T. castaneum.*

2. Botanical Insecticides:

2.1 *Rhizopertha dominica*:

2.1.1 Efficacy:

It is observed from the experimental results that when *R. dominica* are subjected to the exposure to treated pellets with *A. indica* (leaves) *A. indica* (seed), *C. procera* (leaves), *D. fastuosa* (leaves) and *L. camara* (leaves) at 24 hour and 48 hour all the treatments gave no significant mortality response at 0.005%. However, at 48 hour the mortality count was highest and lowest was in case of *A. indica* (leaves) and *L. camara* (leaves) i.e. 79.33% and 49.66% respectively at 1% concentration (Table 2).

2.1.2 Chi square (x^2) test:

Chi square (x^2) test of toxicity responses for all the treatments were insignificant but highly heterogeneous except for *A. indica* seed x^2 value is 14.96 which is significant at df=7, P<0.05.

The significance test for linear regression, slope factor shows that all the formulations of respective botanical insecticides had significantly varied responses (df=7, $p < 0.05$). (Table 3).

2.1.3 Lethal concentration:

The LC_{50} value is the lowest (0.2380) for *A. indica* (leaves) and highest is for *L. Camara* and *C. procera* i.e. 0.5500. (Table 3)

2.1.4 Coefficient of correlation:

A significant positive linear correlation (r=0.92) for *C. procera* and lowest value (r= 0.84) for *L. camara* is observed (Table 3).

2.1.5 Order of toxicity:

A. indica (leaf) is most toxic and *L. camara* leaf is least toxic against *R. dominica* the order of toxicity calculated in *A. Indica* (leaf) > *A. indica* (seed) > *C. procera* (leaf) > *D. fastuosa* (leaf) > *L. camara* (leaf) (Table 2).

2.2 *Sitophilus oryzae*

2.2.1. Efficacy:

The comparative responses observed on *S. oryzae* which are fed on the treated pellets indicate that *C. procera*, *D. fastuosa* and *L. camara* at 0.01% resulted in lowest mortality i.e. 8.00% at 48 hour and at 1.0% conc. *A. indica* (leaf) gave highest (83.66%) mortality and *L. camara* leaf gave 54.00% mortality which was lowest at 48 hour (Table 5).

2.2.2 Chi square (x^2) test:

The toxicity response of *L. camara* was significant with value 18.85 (significant at df = 7, P <0.01 level) while values for other treatments are highly heterogeneous but insignificant.

From the simple linear regression analysis it is found that slope factors of *A. indica* (leaf) and *L. camara* (leaf) have highly significant difference (df=7, P<0.05) (Table 6).

2.2.3 Lethal concentration:

It is observed that the LC_{50} value for *L. camara* (leaves) is the highest i.e. 0.4366 and is the lowest for *A. indica* (leaves) which is 0.1612 (Table 6).

2.2.3 Coefficient of correlation:

A significant positive linear correlation (r=0.89) for *A. indica* (seed) and *C. procera* (leaves) and a lowest value (r=0.86) was noted for *D. fastuosa* (leaves) (Table 6).

2.2.4 Order of toxicity:

A. indica (leaves) caused highest mortality i.e. 83.66% while *L. camara* caused lowest mortality i.e. 54.00%. The order of toxicity for all biocides is *A. indica* (leaf) > *A. indica* (seed) > *C. procera* (leaf) > *D. fastuosa* (leaf) > *L. camara* (leaf) (Table 5).

2.3 *Tribolium castaneum*:

2.3.1 Efficacy:

The data presented in table shows that when *T. castaneum* adults are allowed to feed on the treated pellets with various conc. of biocides the highest mortality (73.33%) is observed at 1% conc. of *A. indica* (leaves) *Lantana camara* resulted in lowest mortality i.e. 51.66. The mortality decreases with decrease in concentration as evident at 0.005% conc. for different biocides at this concentration no significant mortality was observed not even at prolonged exposure time (Table 8).

2.3.2 Chi square (x^2) test:

The toxicity response of *A. indica* (seed) is heterogeneous with significant value 16.49 (df=7,) P <0.05) but chi square (x^2) test values for all other treatments are insignificantly heterogeneous.

As revealed by the transformed mortality graph highest slope factor (β) was recorded for *A. indica* (leaf) i.e. 68.00 and lowest 43.55 for *L. camara* (leaf) (Table 9).

2.3.3 Lethal concentration:

The lowest LC_{50} value obtained for *A. indica* (leaf) was 0.2750 while ıighest value 0.5000 is noted for *D. fastuosa* (leaf) (Table 9).

2.3.4 Coefficient of correlation:

A significant positive linear correlation (r=0.93) was observed for *A. indica* (leaf) and *A. indica* (seed) and lowest (0.89) for *D. fastuosa* (leaf) (Table 9).

2.3.5 Order of toxicity:

The highest mortality is recorded in case of 1% *A. indica* (leaf) while the lowest is in case of *L. camara*. The order of toxicity is *A. indica* (leaf) > *A. indica* (seed) > *C. procera* (leaf) > *D. fastuosa* (leaf) > *L. camara* (leaf) (Table 8).

2.4 *Callosobruchus chinensis*:

2.4.1 Efficacy:

The observations made on the comparative responses of *C. chinensis* adults which are allowed to feed on treated pellets indicate that highest mortality reaches to 89.00% at 1% concentration of *A. indica* (leaves). The lowest mortality is observed at 1% conc. of *L. camara* (leaves) with the value of 55.00% (Table 11).

2.4.2 Chi square (x^2) test:

The toxicity responses of *A. indica* (seed) *C. procera* (leaf) and *L. camara* (leaf) were insignificantly heterogenous in comparison to significantly heterogenous *D. fastuosa* 17.33 at df = 7, P<0.05 and *A. indica* (18.61) significant at P<0.01 level.

It is observed from the experimental results that the highest slope factor (β) is noted for *A. indica* (leaves) 69.41 and lowest (44.54) for *L. camara* leaves. (Table 12)

2.4.3 Lethal concentration:

It is observed that the LC_{50} value being the highest for *D. fastuosa* i.e. 0.4311 and LC_{50} value is lowest for *A. indica* (leaves) which is 0.0950 (Table 12)

2.4.4 Coefficient of correlation:

A significant positive linear correlation (r= 0.90) is noted for *A. indica* (leaves) and a lowest value (r= 0.83) is obtained for *A. indica* (seed) in case of *C. chinensis* adults (Table 12).

2.4.5 Order of toxicity:

A. indica (leaves) proved to be most effective against *C. chinensis* and *L. camara* (leaves) were found least toxic. The order of toxicity is *A. indica* (leaf) > *A. indica* (seed) > *C. procera* (leaf) > *D. fastuosa* (leaf) > *L. camara* (leaf) (Table 11).

2.5 Efficacy of biocides against four stored grain pests.

2.5.1 *Azadirachta indica* (leaves):

C. chinensis > *S. oryzae* > *R. dominica* > *T. castaneum.*

2.5.2 *Azadirachta indica* (seed):

C. chinensis > *S. oryzae* > *R. dominica* > *T. castaneum.*

2.5.3 *Calotropis procera* (leaves):

C. chinensis > *S. oryzae* > *T. castaneum* > *R. dominica.*

2.5.4 *Datura fastuosa*:

C. chinensis > *S. oryzae* > *T. castaneum* > *R. dominica.*

***2.5.5 Lantana camara*:**

C. chinensis > *S. oryzae* > *T. castaneum* > *R. dominica.*

The results obtained clearly reveal that all the four stored grain pests are highly susceptible at 1% concentration of the applied insecticides and biocides. It is further observed that only 0.005% concentration of insecticides and biocides caused no significant mortality against check while all other concentration of insecticides and biocides were found significantly effective. It is observed that on one hand certain biocides like *A. indica* (leaves and seeds) and *C. procera* (leaves) have shown proportionally high efficacy, while on the other hand biocides like *D. fastuosa* (leaves) and *L. camara* (leaves) showed comparatively lesser efficacy (Fig. 13-32).

Tables and Figures

Table 1:Toxicity of Insecticides/ Plant extracts to *Rhizopertha dominica* adults. (24 hours)

Name of Insecticides/Plant extracts	% mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	5.00 ± 1.00	10.33 ± 0.57	15.00 ± 1.73	21.00 ± 2.00	25.00 ± 2.00	28.00 ± 1.00	32.00 ± 1.00	37.00 ± 2.00
Methyl Parathion	3.00 ± 0.00	8.00 ± 1.00	12.00 ± 0.00	17.00 ± 1.00	21.00 ± 2.64	25.33 ± 0.55	29.33 ± 0.57	34.66 ± 1.15
Dimethoate	5.00 ± 1.00	11.00 ± 1.00	13.00 ± 1.00	15.00 ± 2.00	18.66 ± 1.54	24.00 ± 1.00	26.00 ± 1.00	32.33 ± 0.57
Cypermethrin	4.00 ± 1.00	7.00 ± 0.00	10.33 ± 1.52	12.33 ± 0.57	16.00 ± 1.00	20.00 ± 0.00	27.00 ± 1.00	32.33 ± 1.15
Chlorpyrifos	3.00 ± 0.00	7.00 ± 1.00	10.00 ± 0.00	13.00 ± 1.00	17.00 ± 0.00	21.33 ± 0.57	25.00 ± 0.00	31.00 ± 2.00
Plant extracts								
Azadirachta indica(leaf)	1.66 ± 0.57	7.00 ± 1.00	10.00 ± 1.00	12.00 ± 1.00	15.33 ± 2.08	20.00 ± 1.00	26.33 ± 1.15	31.33 ± 0.57
Azadirachta indica (seed)	1.66 ± 0.57	6.00 ± 1.00	10.00 ± 1.00	13.00 ± 0.00	18.00 ± 1.00	19.00 ± 1.73	24.00 ± 1.00	30.00 ± 2.64
Calotropis procera (leaf)	1.00 ± 0.00	7.00 ± 1.73	9.66 ± 1.15	13.33 ± 1.15	17.00 ± 1.73	21.33 ± 1.52	25.00 ± 2.64	29.00 ± 1.00
Datura fastuosa (leaf)	1.33 ± 0.57	4.00 ± 0.57	7.33 ± 0.57	11.33 ± 1.52	15.66 ± 1.15	20.00 ± 2.00	23.33 ± 0.57	28.66 ± 0.57
Lantana camara (leaf)	1.00 ± 0.00	2.00 ± 0.00	6.00 ± 1.00	8.66 ± 0.577	12.00 ± 2.00	15.33 ± 0.57	18.66 ± 0.57	20.00 ± 1.00
Control	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00

Table 2:Toxicity of Insecticides/ Plant extracts to *Rhizopertha dominica* adults. (48 hours)

Name of Insecticides/Plant extracts	% mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	7.00 ± 1.00	11.00 ± 2.00	25.00 ± 1.73	39.00 ± 0.00	53.00 ± 2.00	65.33 ± 0.57	76.66 ± 0.57	88.00 ± 1.00
Methyl Parathion	5.00 ± 1.00	13.00 ± 1.00	23.33 ± 0.57	35.00 ± 1.00	49.00 ± 1.00	60.00 ± 1.52	71.33 ± 0.57	81.00 ± 1.00
Dimethoate	4.00 ± 0.00	10.00 ± 0.00	22.00 ± 1.00	33.00 ± 2.64	47.66 ± 0.57	60.33 ± 0.57	71.00 ± 0.00	78.66 ± 1.15
Cypermethrin	5.00 ± 0.00	12.00 ± 1.00	21.00 ± 2.64	30.00 ± 2.00	39.33 ± 1.52	53.00 ± 1.00	69.33 ± 0.57	85.66 ± 0.57
Chlorpyrifos	4.00 ± 1.00	9.66 ± 0.57	18.33 ± 0.57	30.00 ± 0.00	35.66 ± 0.57	48.00 ± 1.00	59.33 ± 0.57	73.00 ± 0.00
Plant extracts								
Azadirachta indica (leaf)	4.00 ± 1.00	6.00 ± 1.00	15.00 ± 3.00	29.33 ± 0.57	35.00 ± 0.00	51.33 ± 0.57	63.00 ± 1.00	79.33 ± 1.15
Azadirachta indica (seed)	3.66 ± 0.57	5.33 ± 0.57	18.33 ± 0.57	30.66 ± 1.15	35.00 ± 1.00	49.00 ± 1.00	61.00 ± 1.00	75.00 ± 1.00
Calotropis procera (Leaf)	3.00 ± 1.00	7.00 ± 1.00	17.66 ± 2.08	26.00 ± 1.00	32.33 ± 1.52	43.00 ± 1.00	48.33 ± 1.52	62.66 ± 1.15
Datura fastuosa (Leaf)	3.00 ± 0.00	5.33 ± 0.57	16.33 ± 0.57	27.3 ± 1.52	33.00 ± 0.57	41.33 ± 0.57	47.00 ± 0.00	61.66 ± 2.30
Lantana camara (leaf)	3.00 ± 1.00	4.66 ± 1.15	10.00 ± 1.15	15.00 ± 0.00	25.00 ± 1.00	34.33 ± 0.57	41.33 ± 0.57	49.66 ± 1.15
Control	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00	3.00 ± 1.00

Table 3: Treatment mortality response of *Rhizopertha dominica* adults. (48 hours)

Name of Insecticides	No. of insects	Chi square (x^2)	Coefficient of correlation	Regression equation	Slope (β)	Intercept (t)	LC_{50}	Relative ratio (RR)
Monocrotophos	50	8.02	0.86	81.72x+30.80	81.72	30.80	0.0887	0.114
Methyl Parathion	50	14.38	0.88	56.90x+23.44	56.90	23.44	0.1125	0.183
Dimethoate	50	15.84	0.89	68.08x+22.27	68.08	22.27	0.1175	0.191
Cypermethrin	50	7.85	0.89	84.33x+28.04	84.33	28.04	0.2190	0 357
Chlorpyrifos	50	10.73	0.91	64.76x+21.16	64.76	21.16	0.2925	0.476
Plant extracts								
Azadirachta indica (leaf)	50	8.09	0.86	71.60x+28.55	71.60	28.55	0.2380	0.388
Azadirachta indica (seed)	50	14.96	0.86	69.96x+24.57	69.96	24.57	0.2750	0.448
Calotropis procera (Leaf)	50	10.52	0.92	67.42x+17.02	67.42	17.02	0.5500	0.896
Datura fastuosa (Leaf)	50	12.69	0.89	56.32x+16.25	56.32	16.25	0.6133	1.000
Lantana camara (leaf)	50	9.12	0.84	45.69x+17.62	45.69	17.62	0.5500	0.896

χ^2 Significant values (df =7, P<0.05 =14, P<0.01 =18.5)

Table 4: Toxicity of Insecticides/Plant extracts to *Sitophilus oryzae* adults. (24 hours)

Name of Insecticides/Plant extracts	% mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	7.00 ± 1.00	11.00 ± 1.00	14.33 ± 1.15	20.00 ± 1.00	24.00 ± 2.00	30.66 ± 1.15	38.33 ± 0.57	46.66 ± 0.57
Methyl Parathion	6.00 ± 1.00	10.00 ± 1.00	14.33 ± 2.08	19.00 ± 1.00	28.00 ± 0.00	35.33 ± 1.15	41.00 ± 3.60	47.00 ± 1.73
Dimethoate	7.00 ± 0.00	9.00 ± 1.00	14.33 ± 0.57	20.00 ± 2.00	26.00 ± 0.00	30.00 ± 0.00	38.66 ± 1.15	48.33 ± 2.51
Cypermethrin	7.00 ± 0.00	11.33 ± 0.57	15.66 ± 2.08	24.00 ± 2.00	29.33 ± 1.52	34.00 ± 1.00	40.00 ± 1.00	43.33 ± 0.57
Chlorpyrifos	5.00 ± 1.00	8.00 ± 1.00	12.33 ± 0.57	18.00 ± 2.00	24.00 ± 0.00	29.33 ± 1.15	36.00 ± 2.00	41.33 ± 2.08
Plant extracts								
Azadirachta indica (leaf)	4.00 ± 1.15	8.66 ± 0.57	10.00 ± 1.00	13.33 ± 0.57	16.66 ± 0.57	18.66 ± 1.52	26.00 ± 2.00	34.00 ± 1.00
Azadirachta indica (seed)	4.00 ± 1.15	5.33 ± 0.57	10.00 ± 0.00	12.00 ±1.00	16.00 ± 0.00	18.00 ± 0.00	25.00 ± 1.00	32.33 ± 0.57
Calotropis procera(leaf)	3.00 ± 1.15	5.33 ± 0.57	8.66 ± 1.15	11.33 ± 0.57	14.00 ± 2.00	16.00 ± 2.00	20.33 ± 0.57	26.00 ± 2.00
Datura fastuosa(leaf)	3.00 ± 0.00	4.00 ± 1.00	8.66 ± 0.57	10.66 ± 1.15	12.00 ± 1.00	15.00 ± 3.00	21.00 ± 0.00	24.33 ± 0.57
Lantana camara (leaf)	2.00 ± 0.00	3.33 ± 0.57	4.66 ± 1.15	6.33 ± 0.57	10.66 ± 0.57	13.33 ± 0.57	16.00 ± 2.00	20.66 ± 0.57
Control	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00

Table 5: Toxicity of Insecticides/Plant extracts to *Sitophilus oryzae* adults. (48 hours)

Name of Insecticides/Plant extracts	% mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	8.00 ± 0.00	12.33 ± 1.52	25.66 ± 2.08	41.00 ± 1.00	59.33 ± 1.52	71.33 ± 1.15	83.00 ± 1.73	100.00 ± 0.00
Methyl Parathion	6.00 ± 1.00	11.00 ± 1.73	19.00 ± 1.00	30.66 ± 2.08	43.00 ± 1.00	60.00 ± 3.00	71.00 ± 1.00	86.66 ± 2.08
Dimethoate	5.33 ± 1.52	12.00 ± 1.00	19.00 ± 1.73	28.33 ± 0.57	40.66 ± 2.08	56.00 ± 0.00	68.00 ± 2.00	83.33 ± 0.57
Cypermethrin	4.66 ± 0.57	15.00 ± 1.00	23.33 ± 2.00	36.00 ± 0.00	50.00 ± 0.00	63.00 ± 1.00	79.00 ± 1.00	91.00 ± 1.73
Chlorpyrifos	7.00 ± 1.52	13.00 ± 0.00	17.00 ± 0.57	29.33 ± 1.15	40.00 ± 2.64	52.33 ± 0.57	64.00 ± 1.00	79.33 ± 0.57
Plant extracts								
Azadirachta indica (leaf)	6.00 ± 1.00	12.33 ± 1.52	18.33 ± 2.51	30.00 ± 2.00	43.00 ± 1.73	60.00 ± 0.00	71.00 ± 1.00	83.66 ± 0.57
Azadirachta indica (seed)	6.00 ± 0.00	10.00 ± 1.00	15.00 ± 1.00	30.00 ± 1.00	40.00 ± 0.00	53.00 ± 1.00	69.00 ± 0.00	80.33 ± 1.52
Calotropis procera (Leaf)	4.00 ± 1.00	8.00 ± 1.00	13.00 ± 1.00	21.33 ± 0.57	38.00 ± 0.57	49.00 ± 1.00	59.00 ± 2.00	73.33 ± 0.57
Datura fastuosa (Leaf)	5.00 ± 0.00	8.00 ± 0.00	12.00 ± 2.00	25.33 ± 1.52	35.00 ± 1.73	43.00 ± 0.00	52.33 ± 0.57	60.66 ± 1.15
Lantana camara (leaf)	3.66 ± 0.57	8.00 ± 0.00	15.00 ± 1.00	22.00 ± 1.73	29.00 ± 0.00	34.00 ± 1.73	45.00 ± 0.00	54.00 ± 2.00
Control	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57	3.66 ± 0.57

Table 6: Treatment mortality response of *Sitophilus oryzae* adults. (48 hours)

Name of Insecticides	No. of insects	Chi square (x^2)	Coefficient correlation	Regression equation	Slope (β)	Intercept (t)	LC_{50}	Relative ratio (RR)
Monocrotophos	50	10.97	0.90	78.93x+18.50	78.93	18.50	0.0750	0.171
Methyl Parathion	50	16.77	0.89	75.09x+22.70	75.09	22.70	0.1620	0.371
Dimethoate	50	7.72	0.90	72.04x+21.61	72.04	21.61	0.1925	0.440
Cypermethrin	50	8.94	0.87	77.19x+26.52	77.19	26.52	0.1550	0.355
Chlorpyrifos	50	14.78	0.90	66.91x+21.52	66.91	21.52	0.2230	0.510
Plant extracts								
Azadirachta indica (leaf)	50	8.87	0.88	72.40x+22.98	72.40	22.98	0.1612	0.369
Azadirachta indica (seed)	50	10.76	0.89	70.76x+20.75	70.76	20.75	0.2175	0.498
Calotropis procera (Leaf)	50	12.60	0.89	65.41x+17.34	65.41	17.34	0.275	0.635
Datura fastuosa (Leaf)	50	10.96	0.86	51.70x+17.62	51.70	17.62	0.4366	1.000
Lantana camara (leaf)	50	18.85	0.88	44.88x+15.44	44.88	15.44	0.2772	0.634

χ^2 Significant values (df = 7, $P<0.05 = 14.1$, $P<0.01 = 18.5$)

Table 7: Toxicity of Insecticides/Plant extracts to *Tribolium castaneum* adults. (24 hours)

Name of Insecticides/Plant extract	**% Mortality at various concentrations**							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	5.00 ± 0.00	10.00 ± 1.00	13.33 ± 0.57	17.00 ± 1.00	22.00 ± 0.00	26.00 ± 2.00	32.66 ± 2.51	39.33 ± 1.15
Methyl Parathion	4.00 ± 1.00	11.33 ± 0.57	12.33 ± 0.57	15.00 ± 1.15	20.66 ± 0.57	24.66 ± 1.52	30.66 ± 0.57	34.33 ± 0.57
Dimethoate	5.00 ± 1.00	10.66 ± 1.15	13.66 ± 1.52	17.33 ± 0.57	22.00 ± 1.00	26.66 ± 1.15	31.00 ± 0.00	36.33 ± 2.08
Cypermethrin	5.00 ± 0.00	11.00 ± 2.00	14.00 ± 0.00	17.00 ± 1.00	22.00 ± 2.00	24.66 ± 0.57	28.66 ± 0.57	31.33 ± 0.57
Chlorpyrifos	3.0 ± 1.00	8.66 ± 0.57	11.66 ± 1.52	15.66 ± 1.52	20.66 ± 0.57	27.33 ± 0.57	31.66 ± 1.15	38.00 ± 0.00
Plant extracts								
Azadirachta indica (leaf)	2.66 ± 1.15	5.00 ± 1.00	10.33 ± 0.57	14.00 ± 1.00	17.66 ± 0.57	20.00 ± 1.00	26.00 ± 2.00	30.33 ± 1.15
Azadirachta indica (seed)	2.66 ± 0.57	6.33 ± 1.00	8.00 ± 2.00	11.00 ± 1.00	16.00 ± 0.00	20.33 ± 2.51	24.00 ± 2.64	29.00 ± 1.00
Calotropis procera(leaf)	3.00 ± 0.00	6.33 ± 1.15	9.00 ± 1.00	11.33 ± 1.52	15.66 ± 2.08	20.66 ± 0.57	25.33 ± 0.57	28.66 ± 1.52
Datura fastuosa(leaf)	1.00 ± 0.00	4.00 ± 0.57	6.66 ± 0.57	10.33 ± 1.52	13.00 ± 2.00	15.00 ± 1.00	20.66 ± 0.57	24.00 ± 1.00
Lantana camara (leaf)	1.00 ± 1.00	4.00 ± 1.00	5.66 ± 0.57	8.33 ± 0.57	10.66 ± 0.57	12.00 ± 0.00	14.33 ± 0.57	20.66 ± 0.57
Control	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57	1.66 ± 0.57

Table 8: Toxicity of Insecticides/Plant extracts to *Tribolium castaneum* adults. (48 hours)

Name of Insecticides/Plant extracts	**% Mortality at various concentrations**							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	8.66 ± 1.15	12.00 ± 1.00	25.00 ± 2.00	37.00 ± 0.57	51.00 ± 1.00	63.33 ± 0.57	78.00 ± 1.00	90.33 ± 2.08
Methyl Parathion	6.00 ± 1.00	11.33 ± 0.57	19.33 ± 0.57	30.00 ± 1.00	43.33 ± 0.57	55.00 ± 1.00	68.33 ± 0.57	83.33 ± 1.00
Dimethoate	5.00 ± 1.00	14.00 ± 0.00	20.33 ± 0.57	33.33 ± 0.57	41.00 ± 2.00	50.00 ± 3.46	62.00 ± 2.64	77.66 ± 2.30
Cypermethrin	8.00 ± 1.00	13.66 ± 1.52	21.00 ± 0.00	33.00 ± 1.73	48.00 ± 3.46	59.00 ± 1.00	75.00 ± 3.00	88.00 ± 1.00
Chlorpyrifos	4.00 ± 1.00	10.00 ± 0.00	20.00 ± 3.00	32.00 ± 0.00	43.33 ± 0.57	51.00 ± 2.00	63.66 ± 0.57	78.00 ± 0.00
Plant extracts								
Azadirachta indica (leaf)	7.00 ± 2.00	10.00 ± 1.00	16.00 ± 1.00	23.00 ± 1.00	31.00 ± 0.00	49.00 ± 1.00	60.33 ± 0.57	77.33 ± 0.57
Azadirachta indica (seed)	6.00 ± 0.00	10.00 ± 1.00	15.00 ± 1.00	21.00 ± 1.00	31.33 ± 1.00	42.33 ± 1.52	58.00 ± 2.00	73.00 ± 0.00
Calotropis procera (Leaf)	6.00 ± 1.00	8.00 ± 1.00	12.00 ± 0.00	22.00 ± 1.73	34.00 ± 0.57	41.00 ± 2.00	53.66 ± 0.57	66.66 ± 0.57
Datura fastuosa (Leaf)	5.00 ± 2.00	8.00 ± 1.00	13.00 ± 1.00	23.00 ± 0.00	31.00 ± 1.00	39.00 ± 1.00	50.00 ± 2.64	60.33 ± 2.51
Lantana camara (leaf)	5.00 ± 0.00	7.33 ± 0.57	10.00 ± 1.00	18.00 ± 1.00	25.33 ± 0.57	29.00 ± 0.00	40.00 ± 2.00	51.66 ± 0.57
Control	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00	4.00 ± 1.00

Table 9:Treatment mortality response of *Tribolium castaneum* adults. (48 hours)

Name of Insecticides	No. of insects	Chi square (x^2)	Coefficient of correlation	Regression equation	Slope (β)	Intercept (t)	LC_{50}	Relative ratio (RR)
Monocrotophos	50	8.12	0.87	75.13x+27.43	75.19	27.43	0.0930	0.186
Methyl Parathion	50	15.77	0.89	71.22x+22.30	71.22	22.30	0.1860	0.372
Dimethoate	50	12.89	0.89	63.18x+22.59	63.18	22.59	0.2235	0.447
Cypermethrin	50	8.89	0.88	74.33x+25.18	74.33	25.18	0.1275	0.255
Chlorpyrifos	50	16.83	0.90	69.41x+19.16	69.41	19.16	0.2290	0.458
Plant extracts								
Azadirachta indica(leaf)	50	10.52	0.93	68.00x+17.71	68.00	17.71	0.2750	0.555
Azadirachta indica (seed)	50	16.49	0.93	64.12x+16.61	64.12	16.61	0.3600	0.720
Calotropis procera (Leaf)	50	12.64	0.90	57.98x+16.39	57.98	16.39	0.4288	0.857
Datura fastuosa (Leaf)	50	8.78	0.89	51.61x+16.14	51.61	16.14	0.5000	1.000
Lantana camara (leaf)	50	10.59	0.92	43.85x+12.65	43.85	12.65	0.4288	0.857

χ^2 Significant values (df = 7, P<0.05 = 14.1, P <0.01 = 18.5)

Table 10: Toxicity of Insecticides/Plant extracts to *Callosobruchus chinensis* adults. (24 hours)

Name of Insecticides/Plant extracts	% Mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	3.33 ± 0.57	8.00 ± 1.00	12.00 ± 1.00	19.33 ± 1.52	25.66 ± 0.57	30.00 ± 2.00	38.00 ± 1.00	44.66 ± 0.57
Methyl Parathion	3.00 ± 0.00	7.00 ± 0.00	12.00 ± 1.73	18.66 ± 0.57	22.66 ± 0.57	30.66 ± 2.08	35.33 ± 1.15	43.33 ± 0.57
Dimethoate	3.33 ± 1.52	5.00 ± 1.00	11.00 ± 0.57	18.66 ± 1.15	25.33 ± 2.08	28.00 ± 0.00	32.00 ± 0.00	39.33 ± 1.52
Cypermethrin	3.00 ± 1.00	6.00 ± 1.00	13.00 ± 2.00	18.00 ± 1.73	23.33 ± 0.57	30.66 ± 1.15	34.66 ± 0.57	42.00 ± 0.00
Chlorpyrifos	3.00 ± 0.00	7.00 ± 1.00	13.00 ± 1.73	18.66 ± 2.08	23.33 ± 1.52	29.33 ± 1.15	32.33 ± 0.57	39.66 ± 0.57
Plant extracts								
Azadirachta indica (leaf)	2.66 ± 0.57	5.00 ± 1.00	8.33 ± 0.57	11.00 ± 0.00	17.33 ± 1.52	22.00 ± 1.00	27.33 ± 1.15	33.33 ± 0.57
Azadirachta indica (seed)	2.66 ± 1.15	6.00 ± 1.00	9.00 ± 1.73	12.00 ± 1.00	15.00 ± 3.00	17.33 ± 1.52	23.00 ± 1.00	33.33 ± 0.57
Calotropis procera(leaf)	2.66 ± 0.57	3.00 ± 0.00	4.00 ± 1.00	6.00 ± 2.00	10.00 ± 1.52	12.66 ± 1.00	16.00 ± 2.00	21.33 ± 1.15
Datura fastuosa(leaf)	2.00 ± 0.00	3.00 ± 1.00	4.00 ± 0.00	7.33 ± 0.57	10.00 ± 2.00	16.66 ± 0.57	18.00 ± 1.00	20.33 ± 0.57
Lantana camara (leaf)	2.00 ± 0.00	3.33 ± 0.57	6.00 ± 1.00	10.66 ± 0.57	12.00 ± 1.00	14.66 ± 0.57	18.00 ± 2.00	20.66 ± 2.08
Control	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57	2.66 ± 0.57

Table 11: Toxicity of Insecticides/Plant extracts to *Callosobruchus chinensis* adults. (48 hours)

Name of Insecticides/Plant extracts	% Mortality at various concentrations							
Insecticides	**0.005%**	**0.01%**	**0.025%**	**0.05%**	**0.1%**	**0.25%**	**0.5%**	**1.0%**
Monocrotophos	8.33 ± 1.15	15.00 ± 3.00	28.00 ± 2.00	41.00 ± 1.00	58.33 ± 2.08	71.33 ± 2.08	83.00 ± 3.00	100.00 ± 0.00
Methyl Parathion	8.00 ± 2.00	12.33 ± 1.15	23.00 ± 2.00	38.00 ± 1.00	46.00 ± 2.64	59.33 ± 1.52	73.33 ± 1.52	88.00 ± 1.54
Dimethoate	5.33 ± 0.57	12.00 ± 0.00	20.00 ± 1.00	31.00 ± 1.00	43.00 ± 1.00	51.33 ± 1.15	67.00 ± 2.64	80.66 ± 0.57
Cypermethrin	6.33 ± 0.57	15.33 ± 0.57	28.00 ± 1.00	39.00 ± 2.00	51.33 ± 0.57	63.00 ± 1.00	85.00 ± 0.00	100.00 ± 0.00
Chlorpyrifos	6.00 ± 0.00	13.00 ± 2.00	21.00 ± 0.00	30.33 ± 0.57	37.33 ± 1.00	48.00 ± 3.60	60.66 ± 1.15	78.66 ± 1.00
Plant extracts								
Azadirachta indica (leaf)	7.00 ± 2.00	13.00 ± 1.00	28.33 ± 0.57	40.00 ± 1.00	52.00 ± 2.00	63.00 ± 2.00	75.00 ± 2.64	89.00 ± 1.00
Azadirachta indica (seed)	7.33 ± 0.57	10.33 ± 0.57	20.33 ± 2.08	33.00 ± 2.00	48.00 ± 1.00	60.00 ± 0.00	70.00 ± 1.00	83.33 ± 1.15
Calotropis procera(leaf)	6.00 ± 1.00	8.00 ± 1.00	15.00 ± 1.00	22.00 ± 1.00	33.33 ± 0.57	46.00 ± 0.00	61.33 ± 0.57	75.33 ± 2.08
Datura fastuosa(leaf)	6.00 ± 0.00	7.33 ± 0.00	13.00 ± 1.00	20.33 ± 0.57	31.00 ± 3.00	45.33 ± 0.57	52.00 ± 1.00	64.33 ± 0.57
Lantana camara (leaf)	6.00 ± 0.00	8.00 ± 2.00	14.00 ± 2.00	23.00 ± 1.00	33.33 ± 1.52	41.33 ± 0.57	49.00 ± 0.00	55.00 ± 1.73
Control	5.33 ± 0.577	5.33 ± 0.57	5.33 ± 0.57	5.33 ± 0.57	5.33 ± 0.57	5.33 ± 0.57	5.33 ± 0.57	5.33 ± 0.57

Table 12: Treatment mortality response of *Callosobruchus chinensis* adults. (48 hours)

Name of Insecticides	No. of insects	Chi square (x^2)	Coefficient of correlation	Regression equation	Slope (β)	Intercept (t)	LC_{50}	Relative ratio (RR)
Monocrotophos	50	6.32	0.84	72.69x+27.99	72.69	27.99	0.0760	0.176
Methyl Parathion	50	8.64	0.84	66.84x+25.99	66.84	25.99	0.1440	0.334
Dimethoate	50	13.14	0.83	66.77x+24.63	66.77	24.63	0.2250	0.521
Cypermethrin	50	15.67	0.91	73.90x+21.49	73.90	21.40	0.950	0.220
Chlorpyrifos	50	8.64	0.89	61.83x+19.75	61.83	19.75	0.2375	0.550
Plant extracts								
Azadirachta indica (leaf)	50	18.61	0.90	69.41x+19.16	69.41	19.16	0.0950	0.220
Azadirachta indica (seed)	50	12.38	0.83	65.36x+18.89	65.36	18.89	0.1288	0.298
Calotropis procera(leaf)	50	10.96	0.87	51.95x+17.39	51.95	17.39	0.3110	0.721
Datura fastuosa(leaf)	50	17.33	0.86	51.03x+16.99	51.03	16.99	0.4311	1.000
Lantana camara (leaf)	50	7.13	0.88	44.54x+12.07	44.54	12.07	0.3110	0.721

χ^2 Significant values (df = 7, $P<0.05 = 14.1$, $P<0.01 = 18.5$)

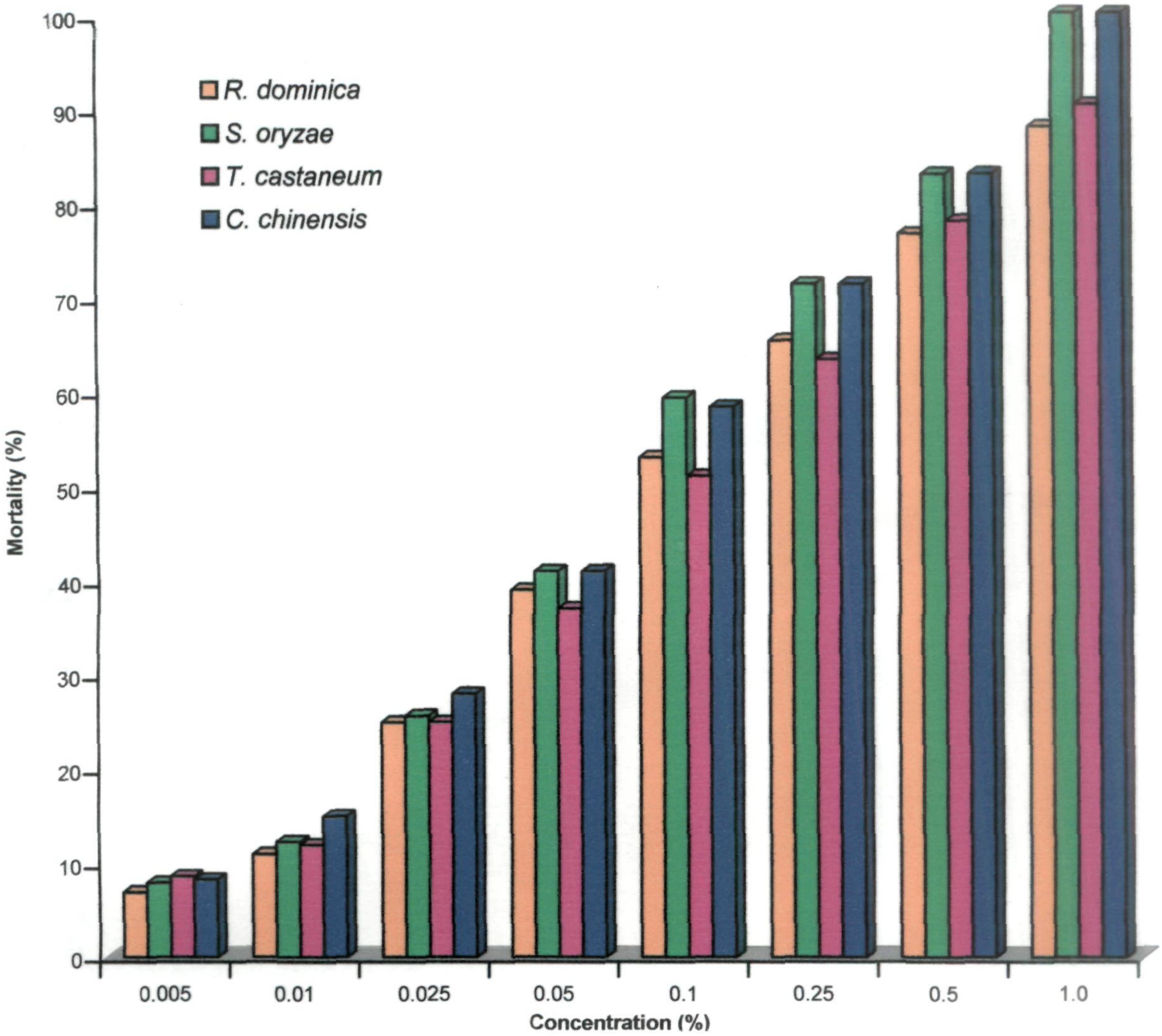

Fig. 13: Comparative efficacy of Monocrotophos against four stored grain pests

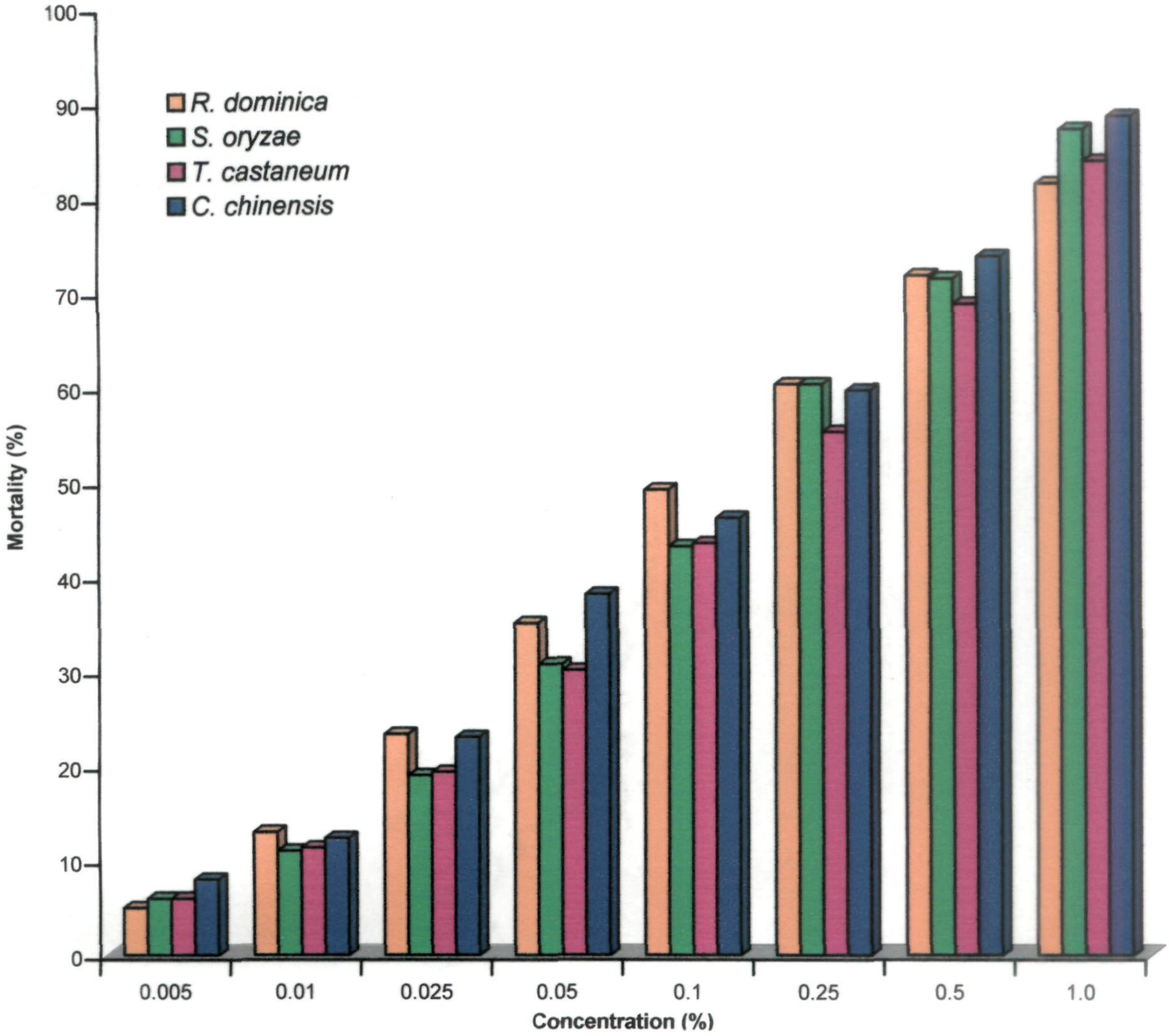

Fig. 14: Comparative efficacy of Methyl paration against four stored grain pests

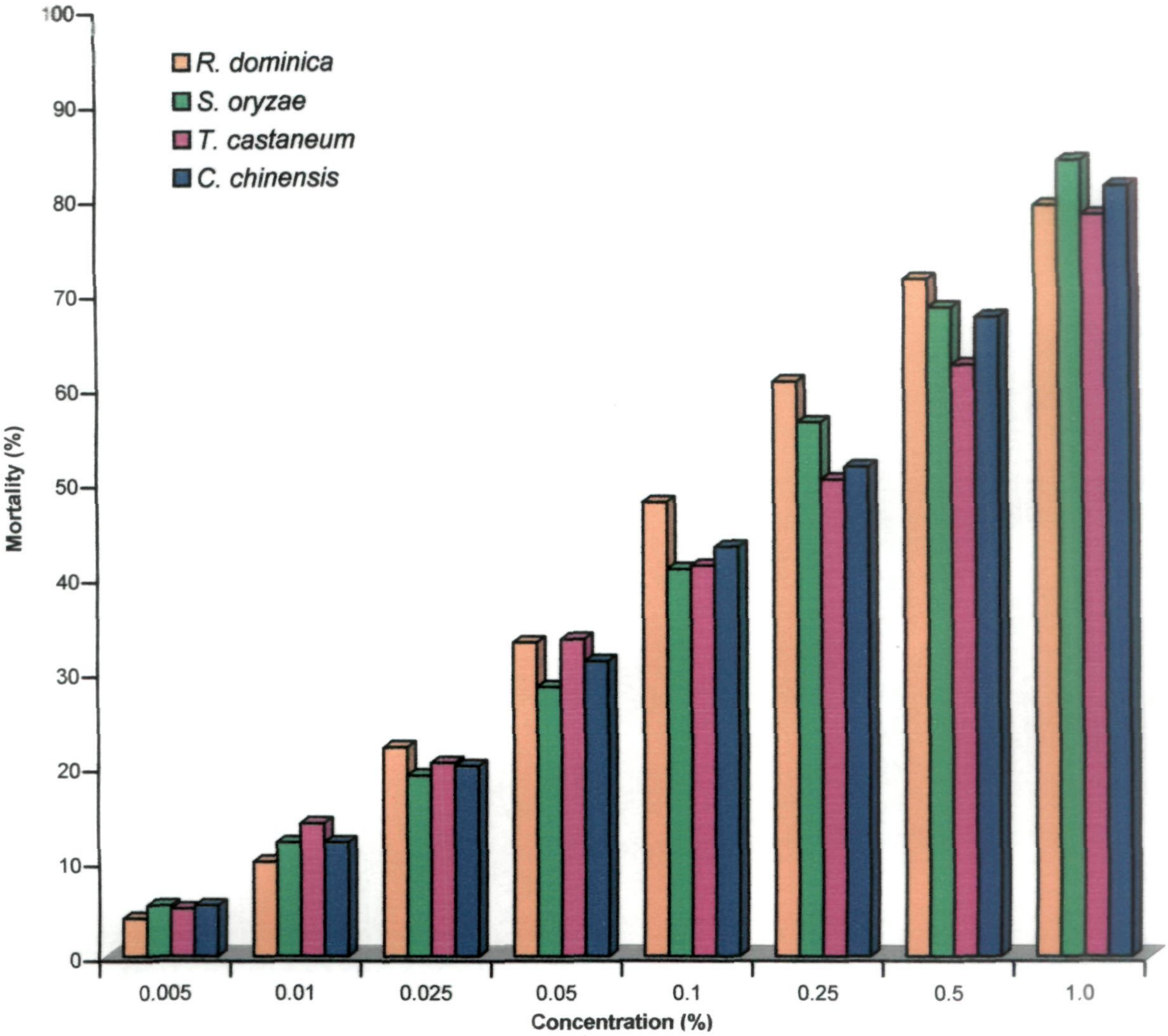

Fig. 15: Comparative efficacy of Dimethoate against four stored grain pests

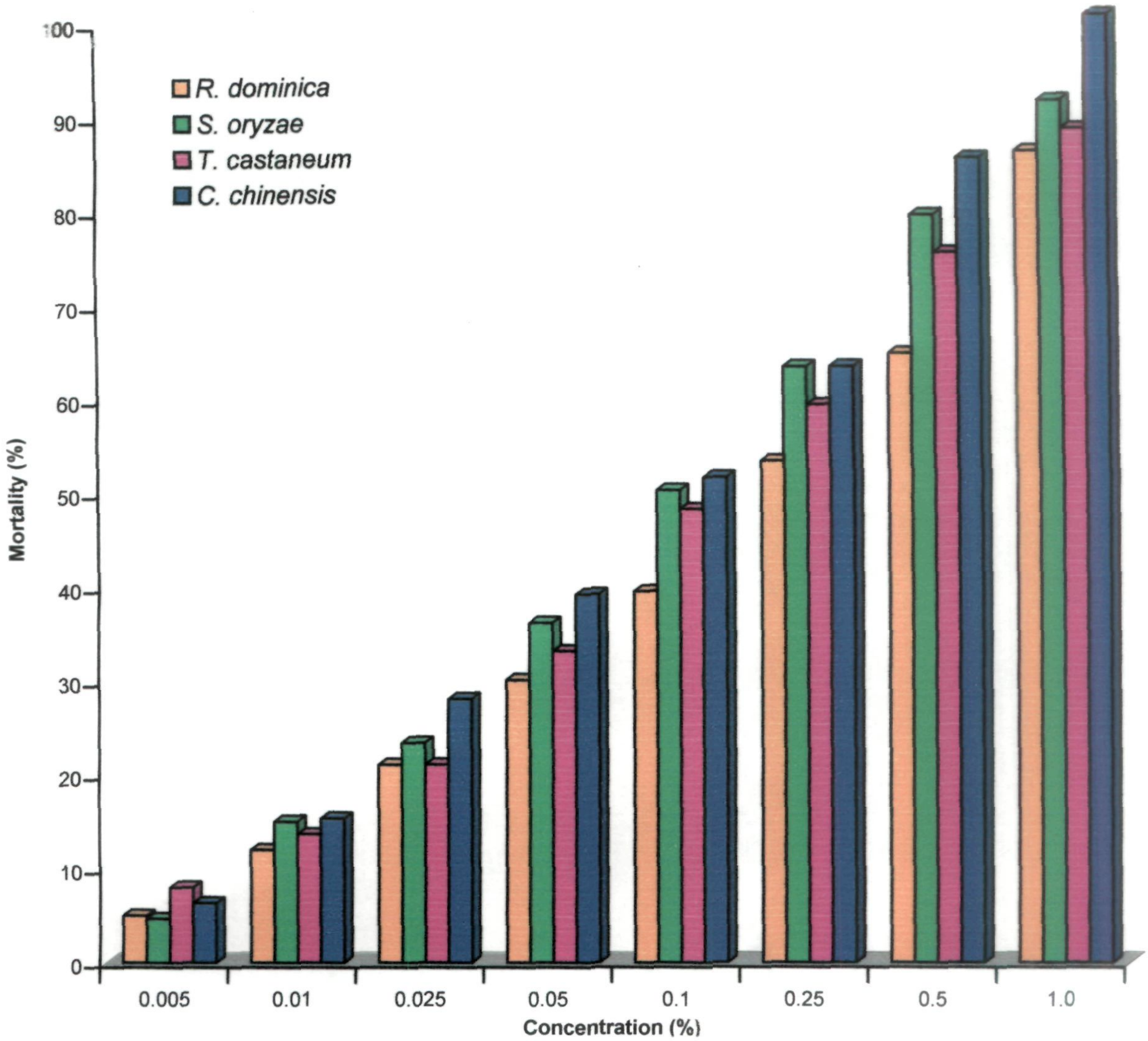

Fig. 16: Comparative efficacy of Cypermethrin against four stored grain pests

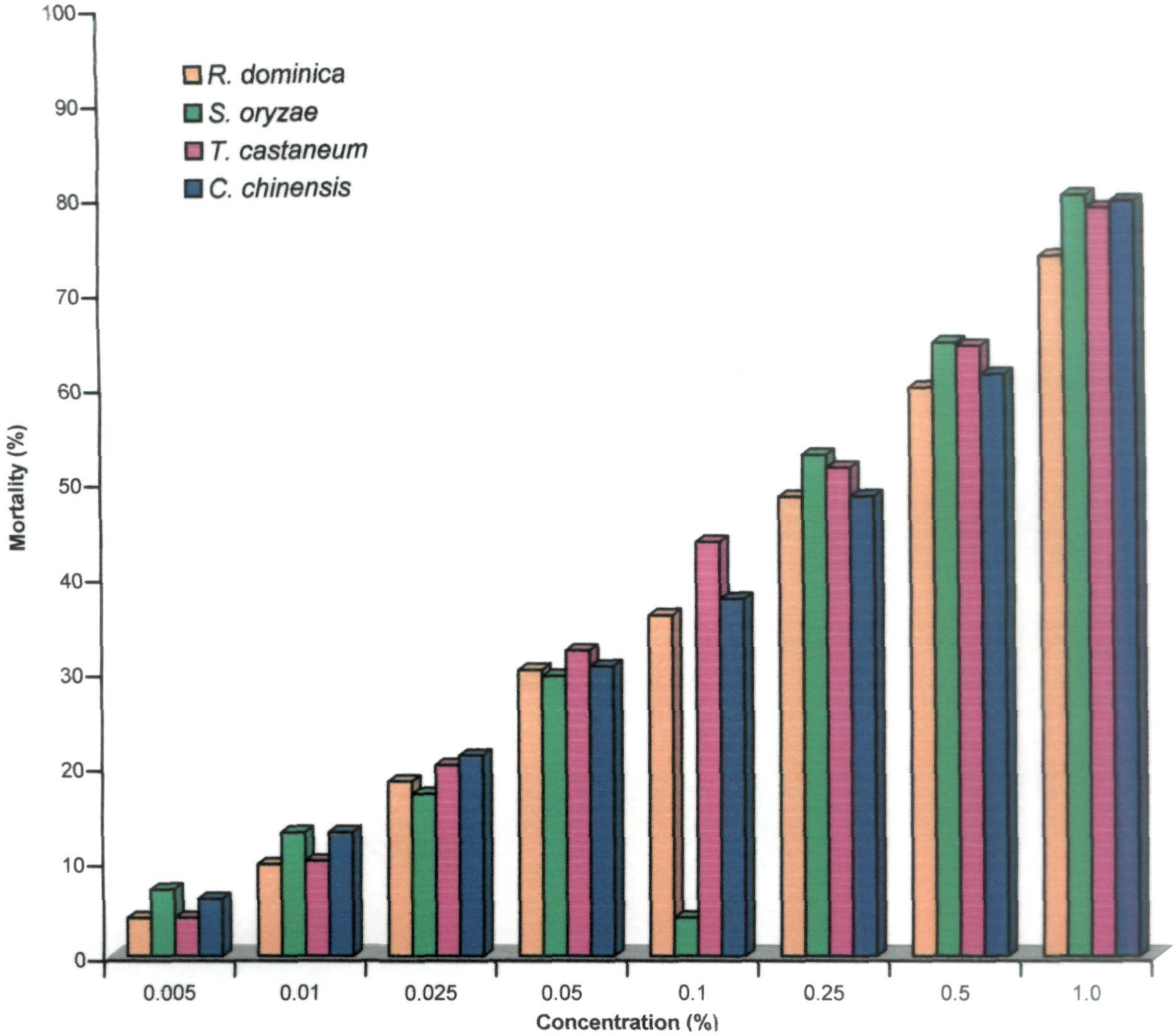

Fig. 17: Comparative efficacy of Chlorpyriphos against four stored grain pests

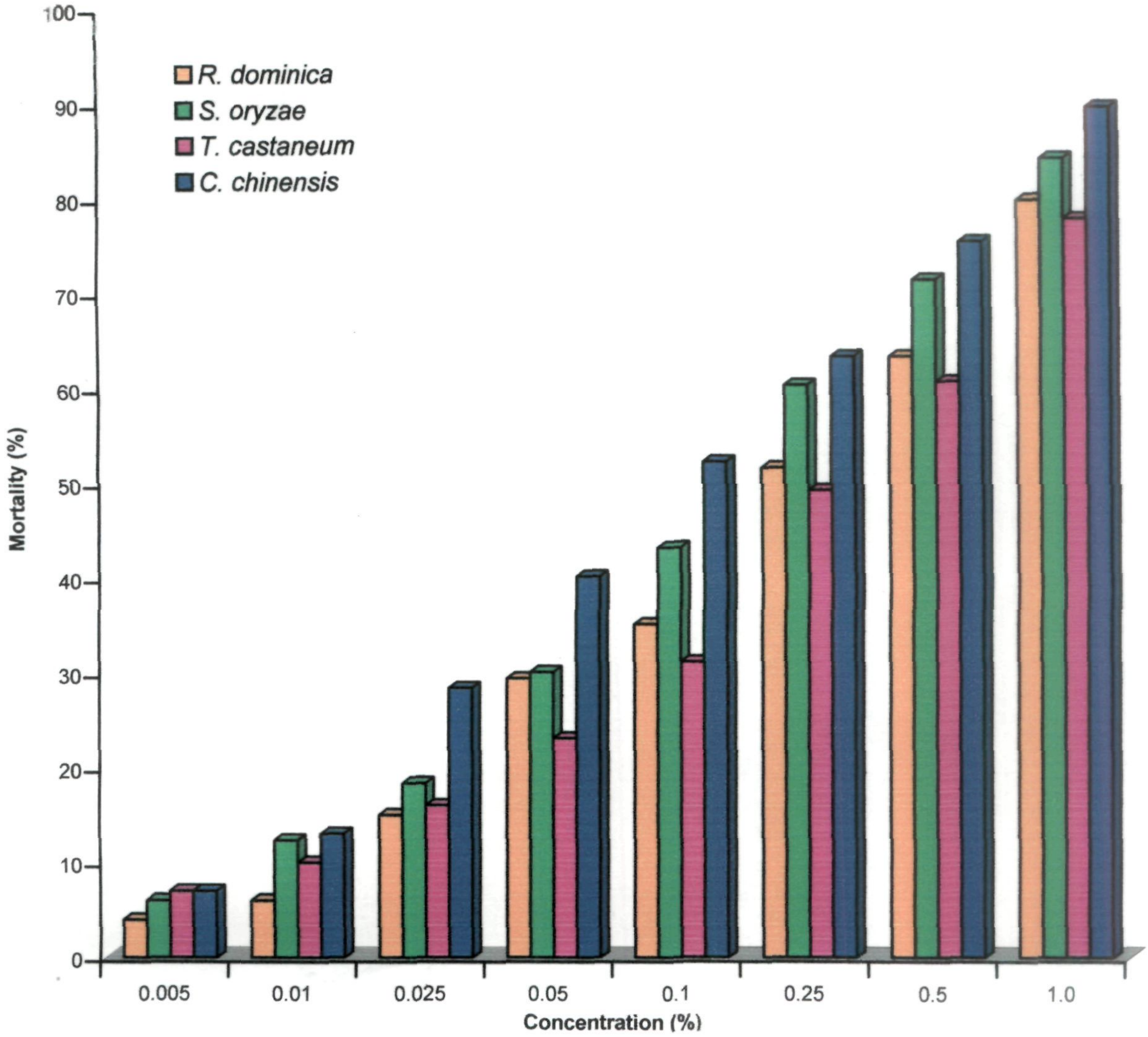

Fig. 18: Comparative efficacy of *A. indica* (leaf) against four stored grain pests

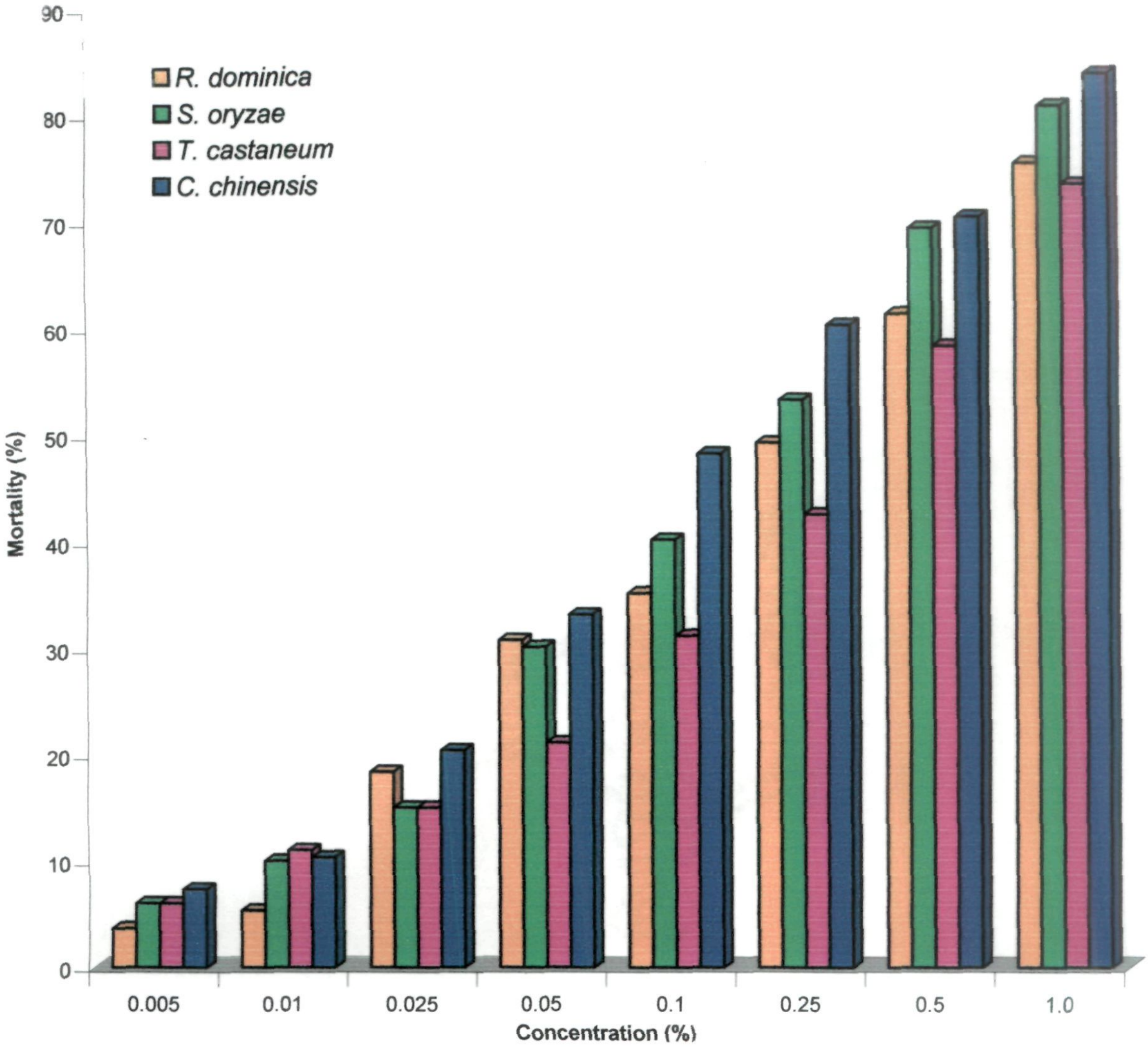

Fig. 19: Comparative efficacy of *A. indica* (seed) against four stored grain pests

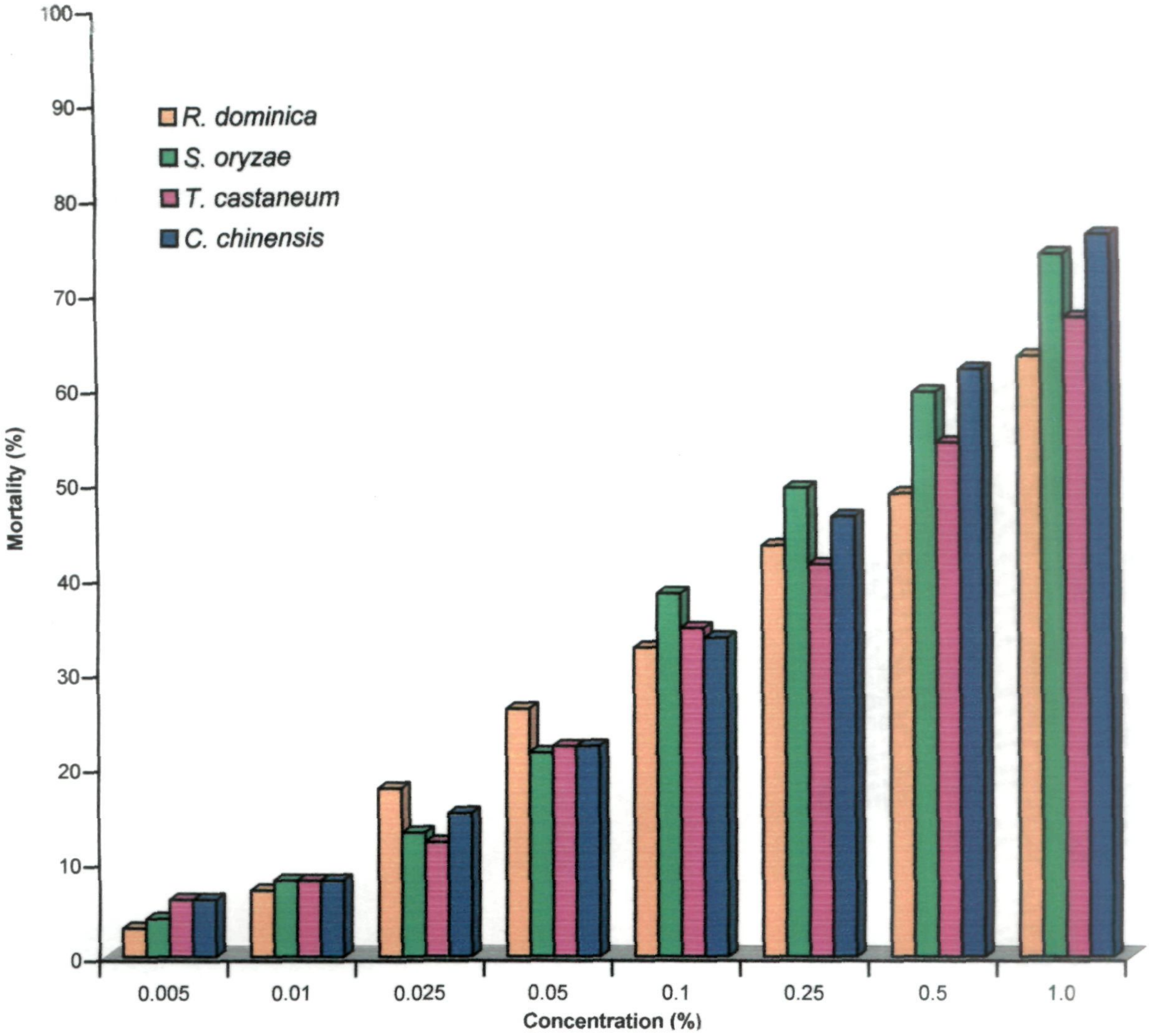

Fig. 20: Comparative efficacy of *C. procera* (leaf) against four stored grain pests

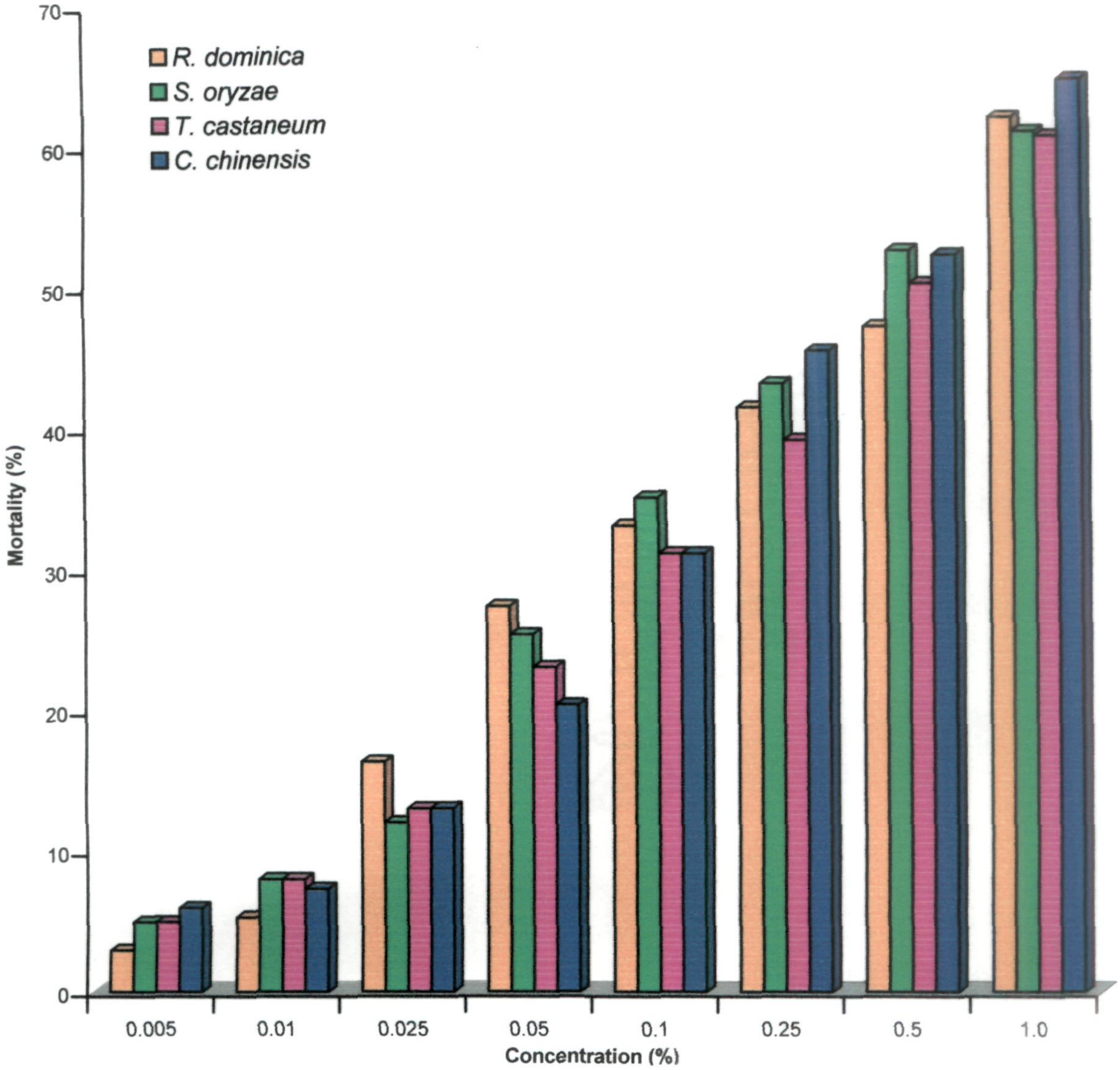

Fig. 21: Comparative efficacy of *D. fastuosa* (leaf) against four stored grain pests

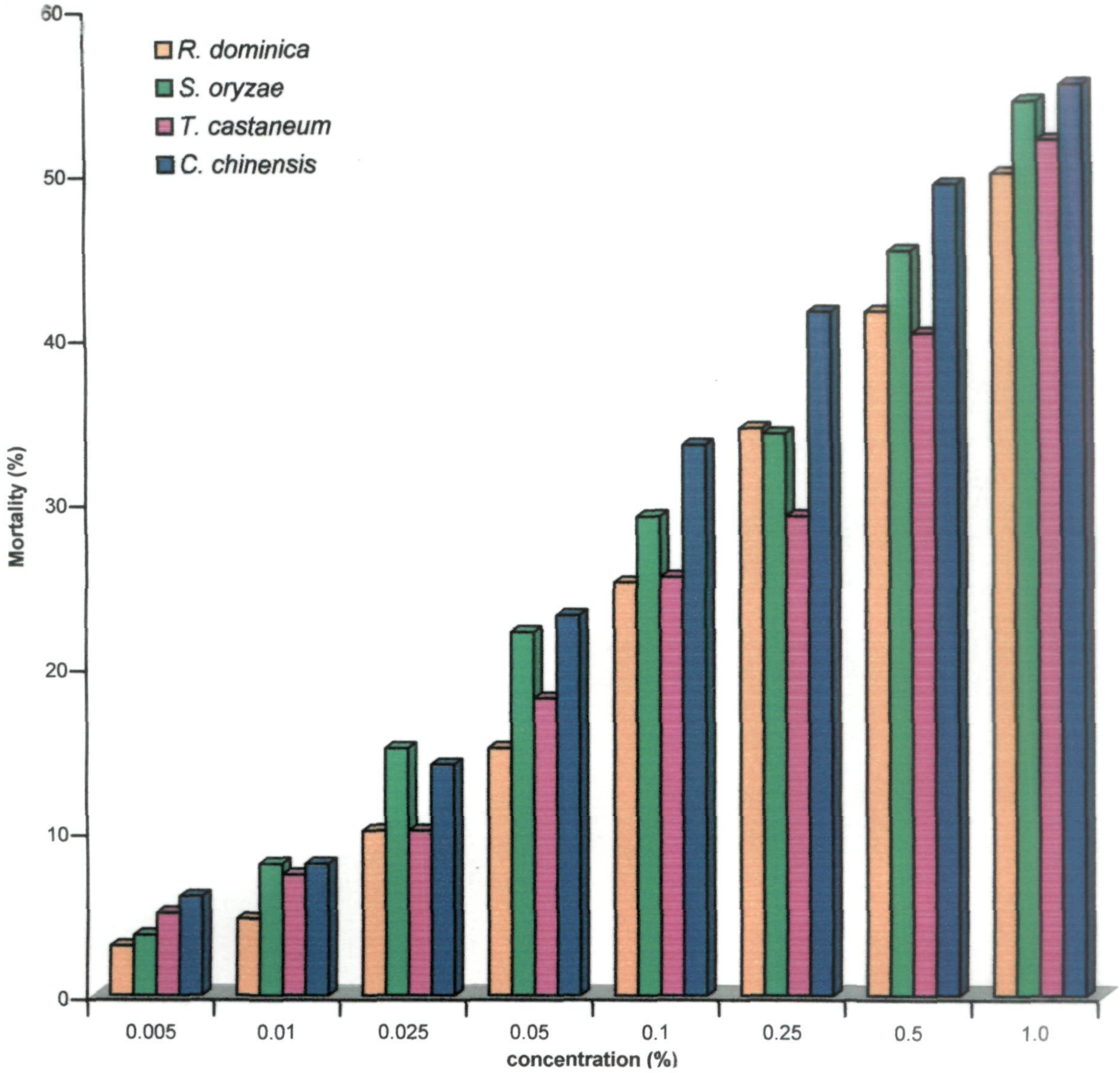

Fig. 22: Comparative efficacy of *L. camara* (leaf) against four stored grain pests

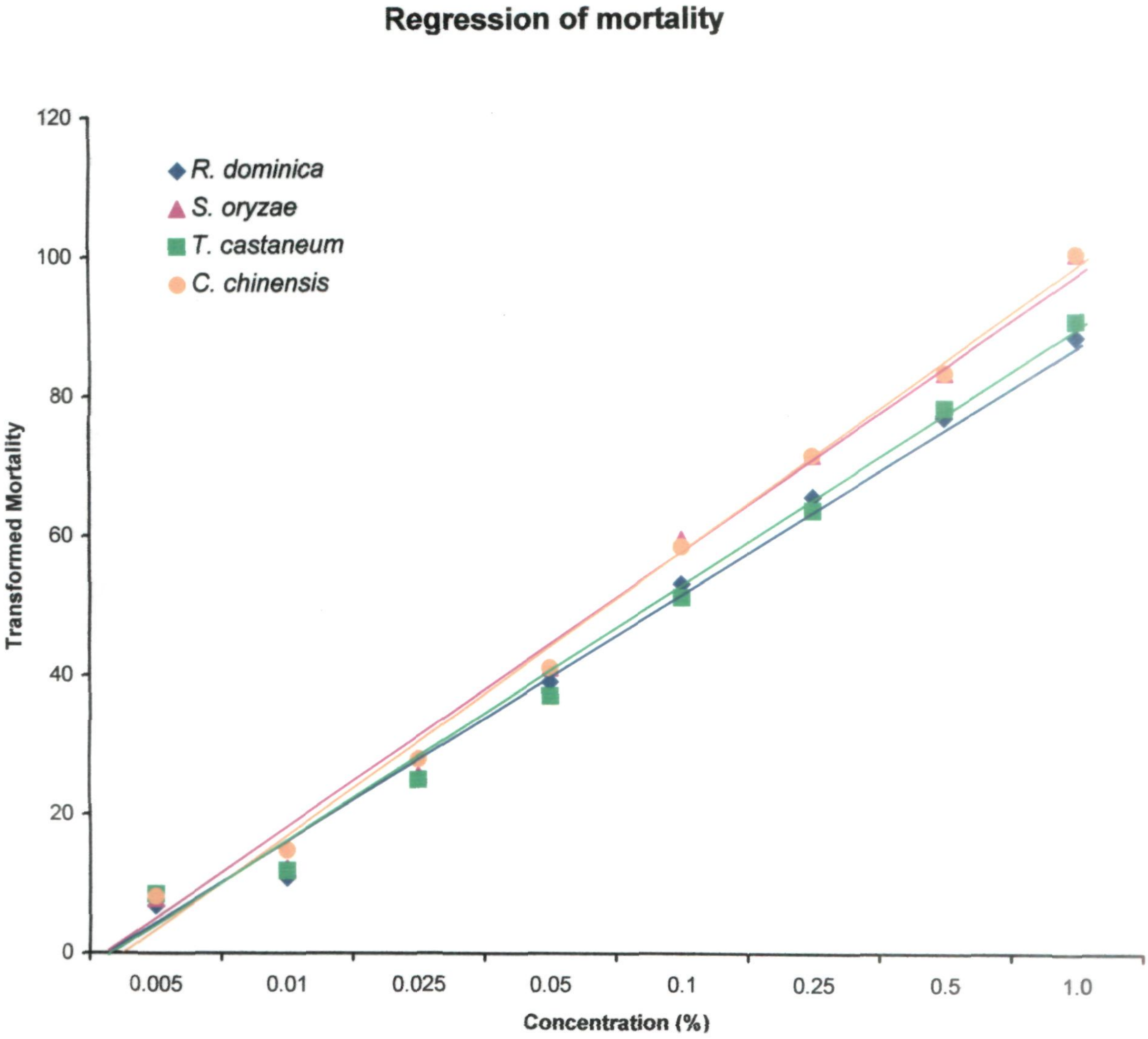

Fig. 23: Transformed mortality response (TMR) in terms of regression lines against Monocrotophos

Regression mortality

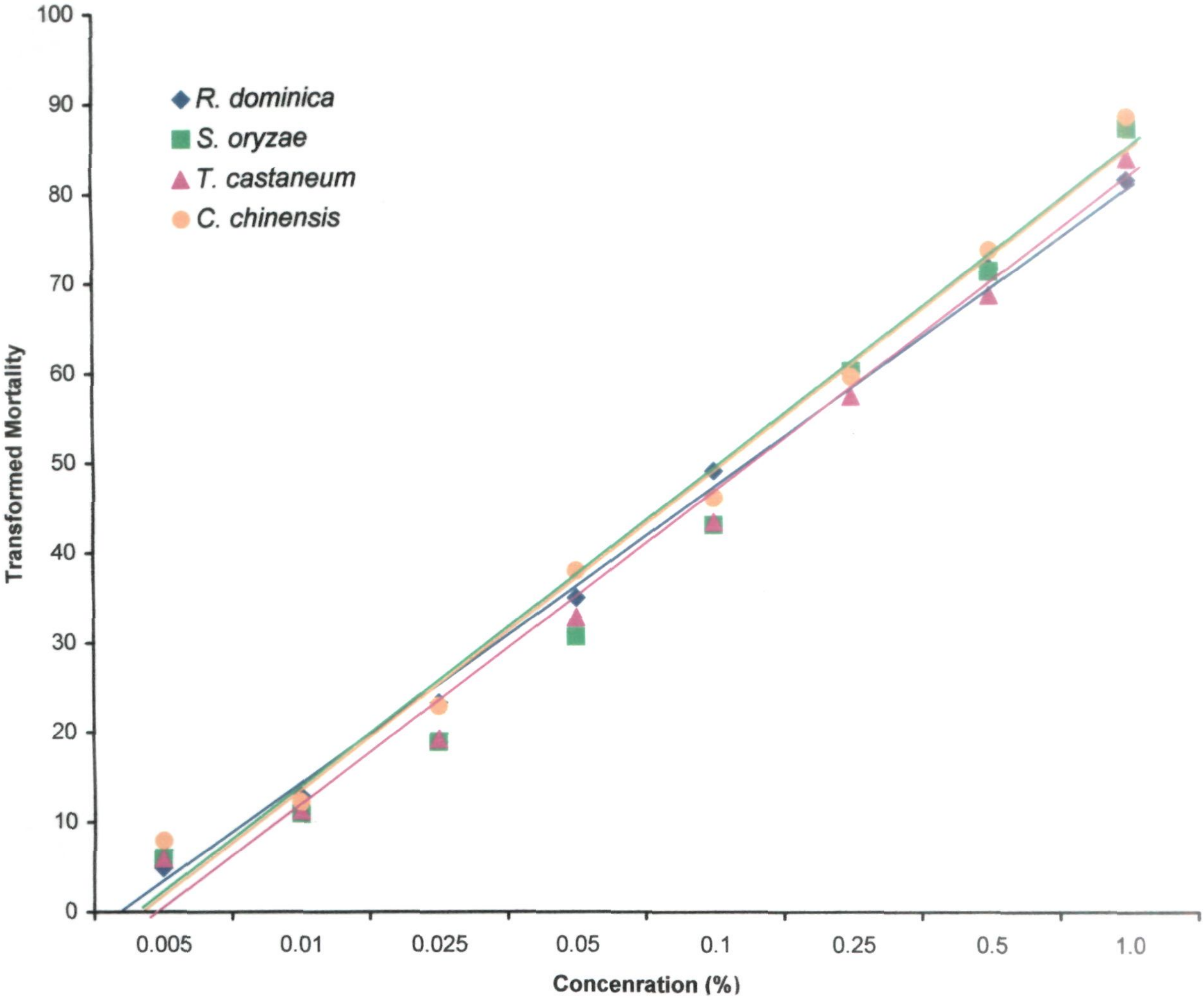

Fig. Fig. 24: Transformed mortality response (TMR) in terms of regression lines against Methyl parathion

Regression of mortality

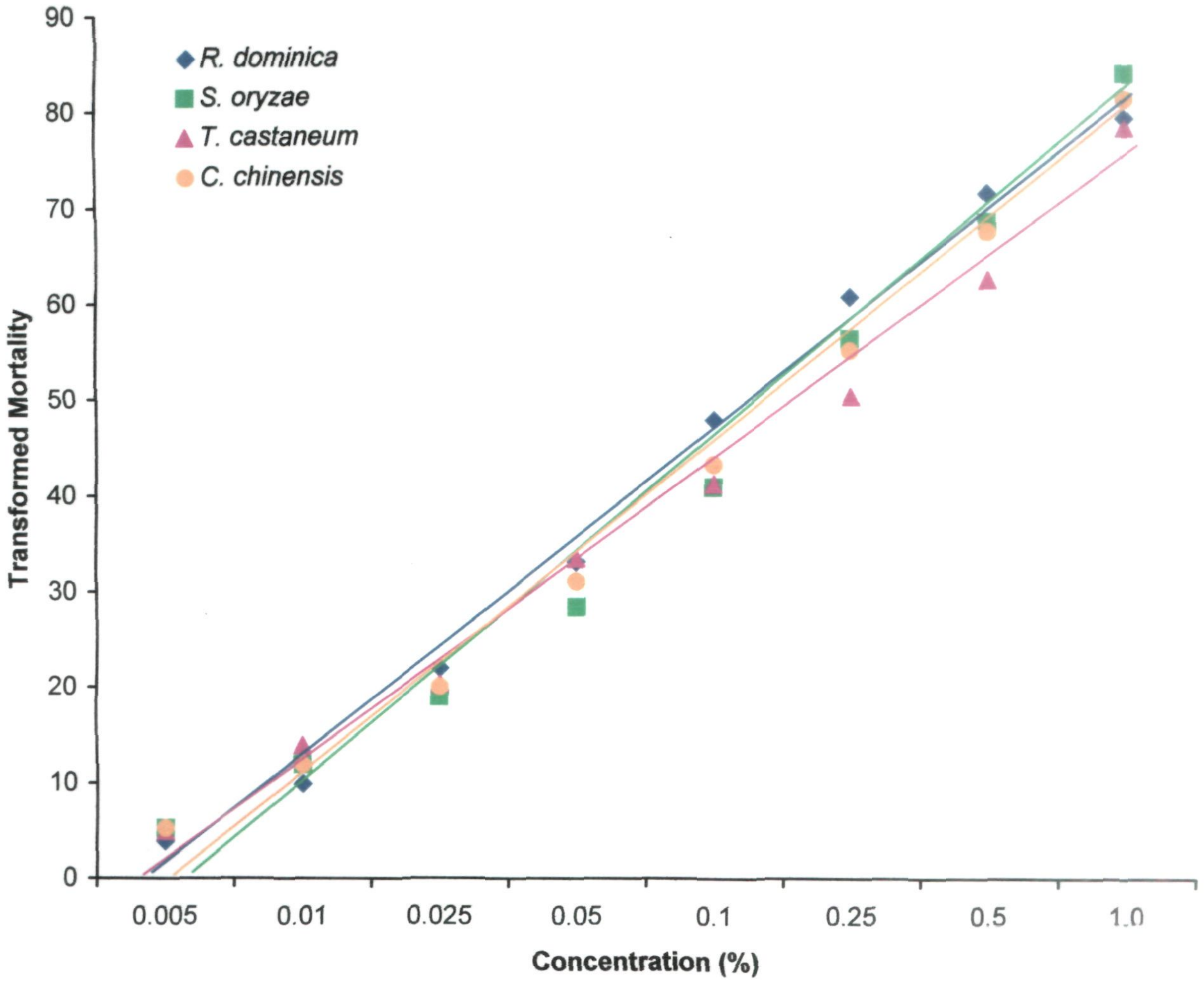

Fig. 25: Transformed mortality response (TMR) in terms of regression lines against Dimethoate

Regression of mortality

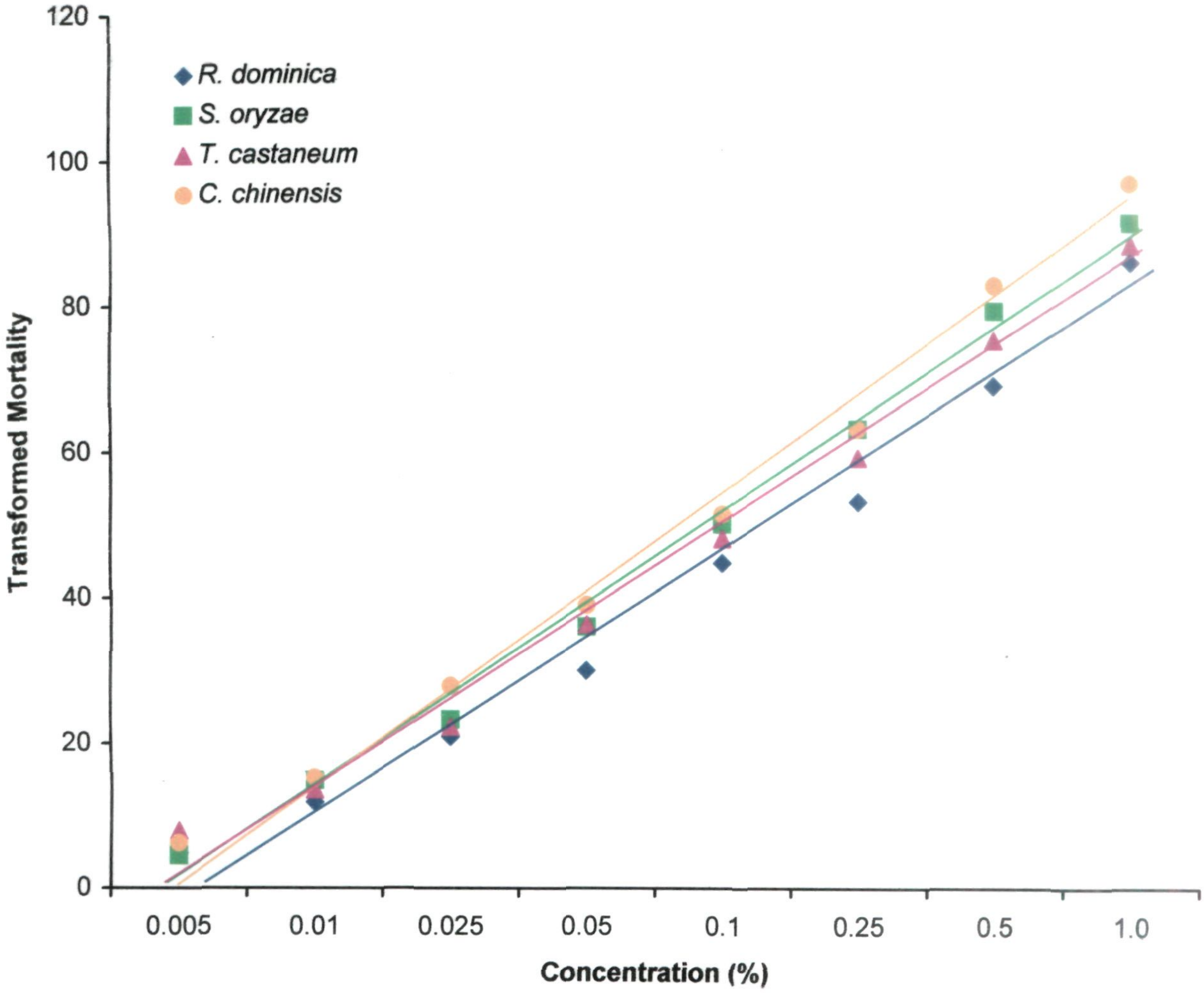

Fig. 26: Transformed mortality response (TMR) in terms of regression lines against Cypermethrin

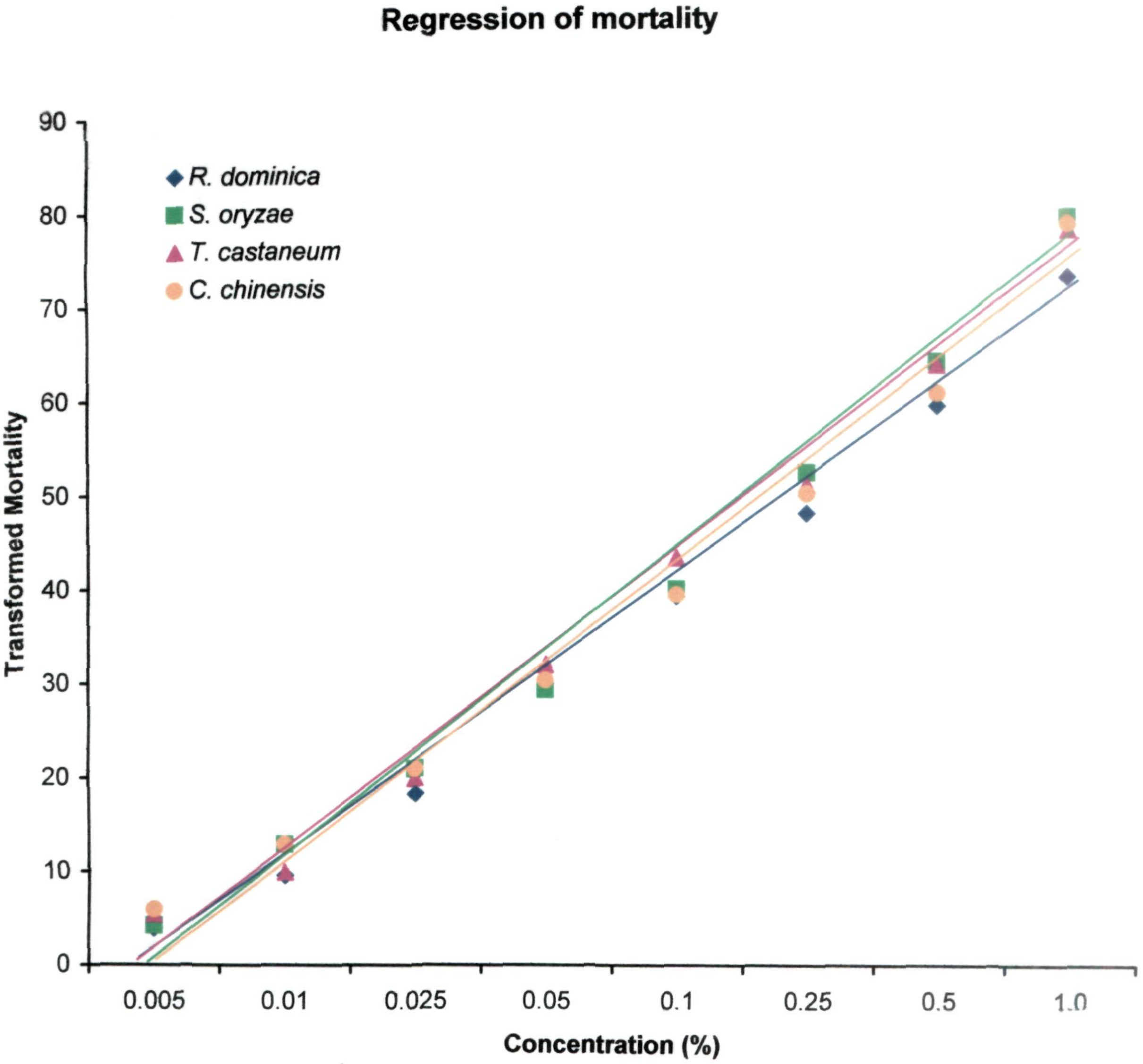

Fig. 27: Transformed mortality response (TMR) in terms of regression lines against Chlorpyrifos

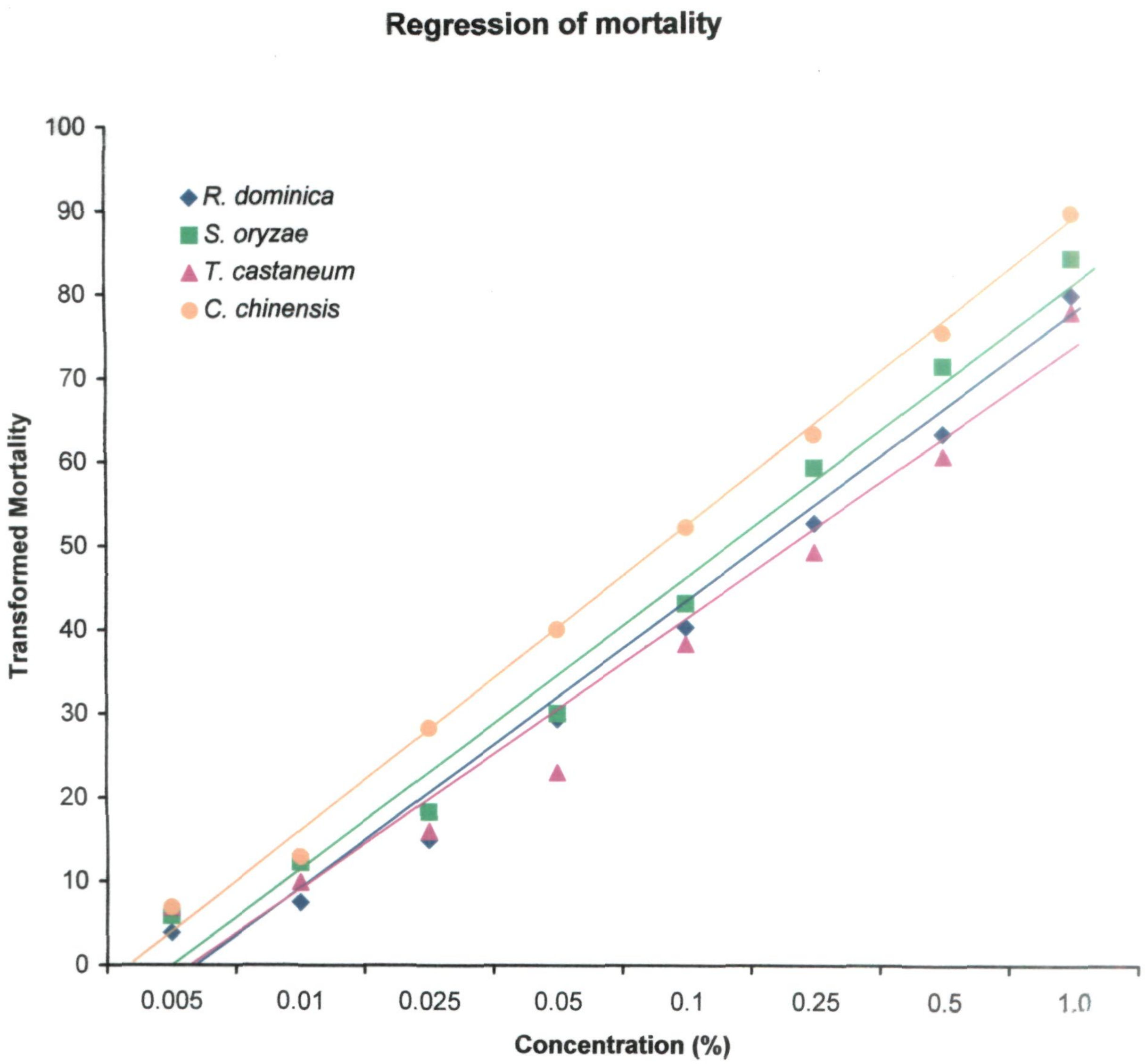

Fig. 28: Transformed mortality response (TMR) in terms of regression lines against *A. indica* (leaf)

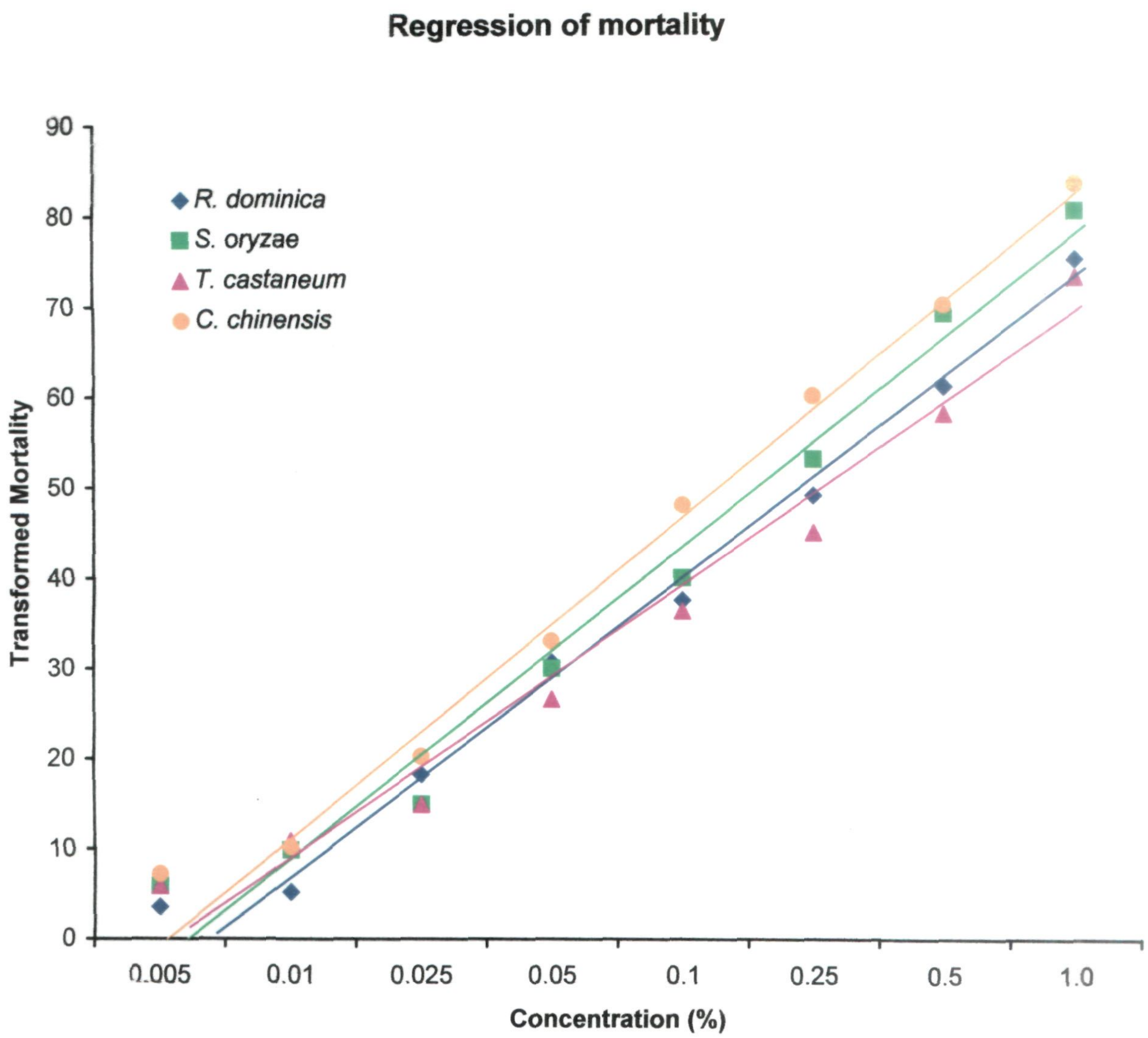

Fig. 29: Transformed mortality response (TMR) in terms of regression lines against *A. indica* (seed)

Regression of mortality

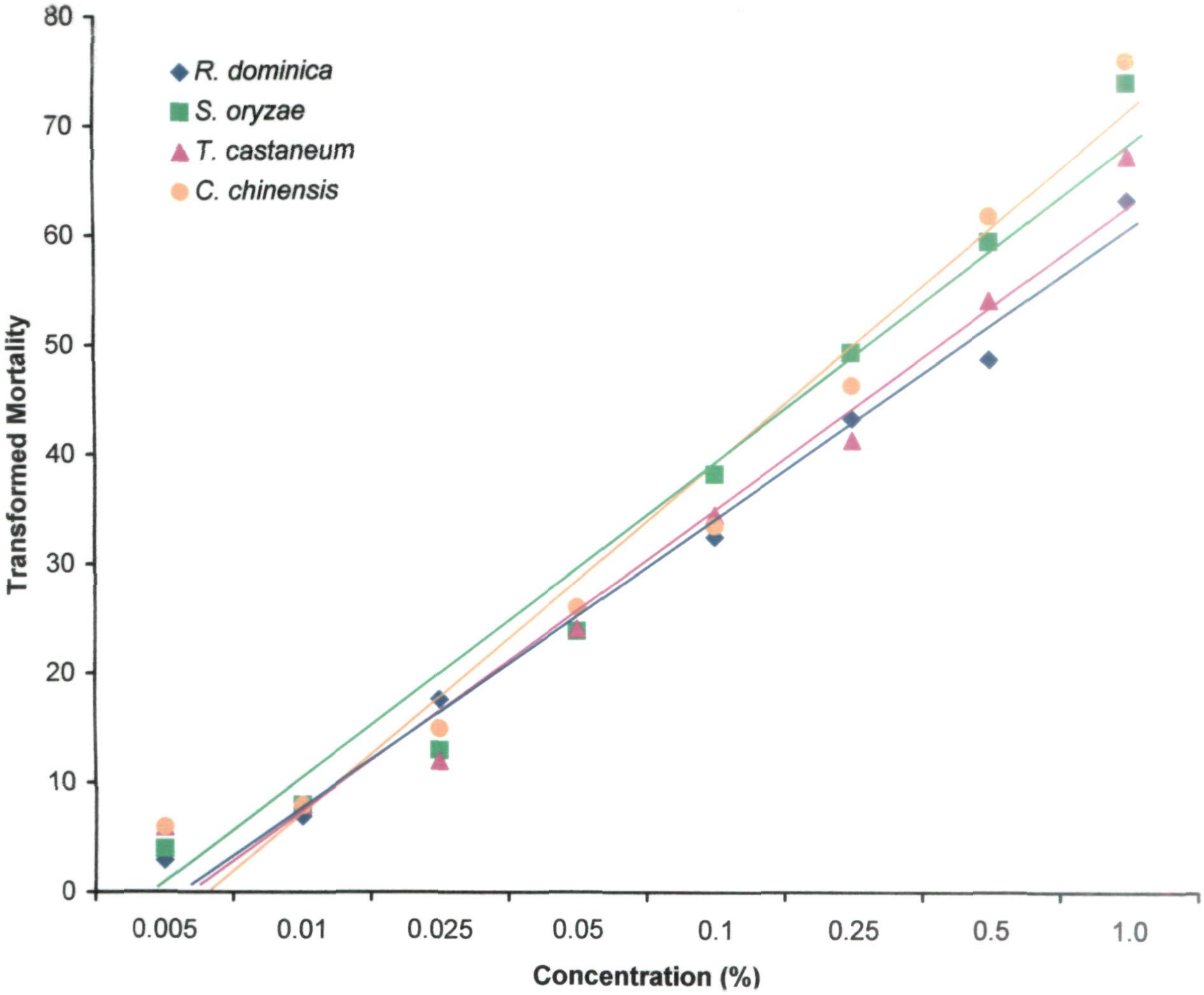

Fig. 30: Transformed mortality response (TMR) in terms of regression lines against *C. procera* (leaf)

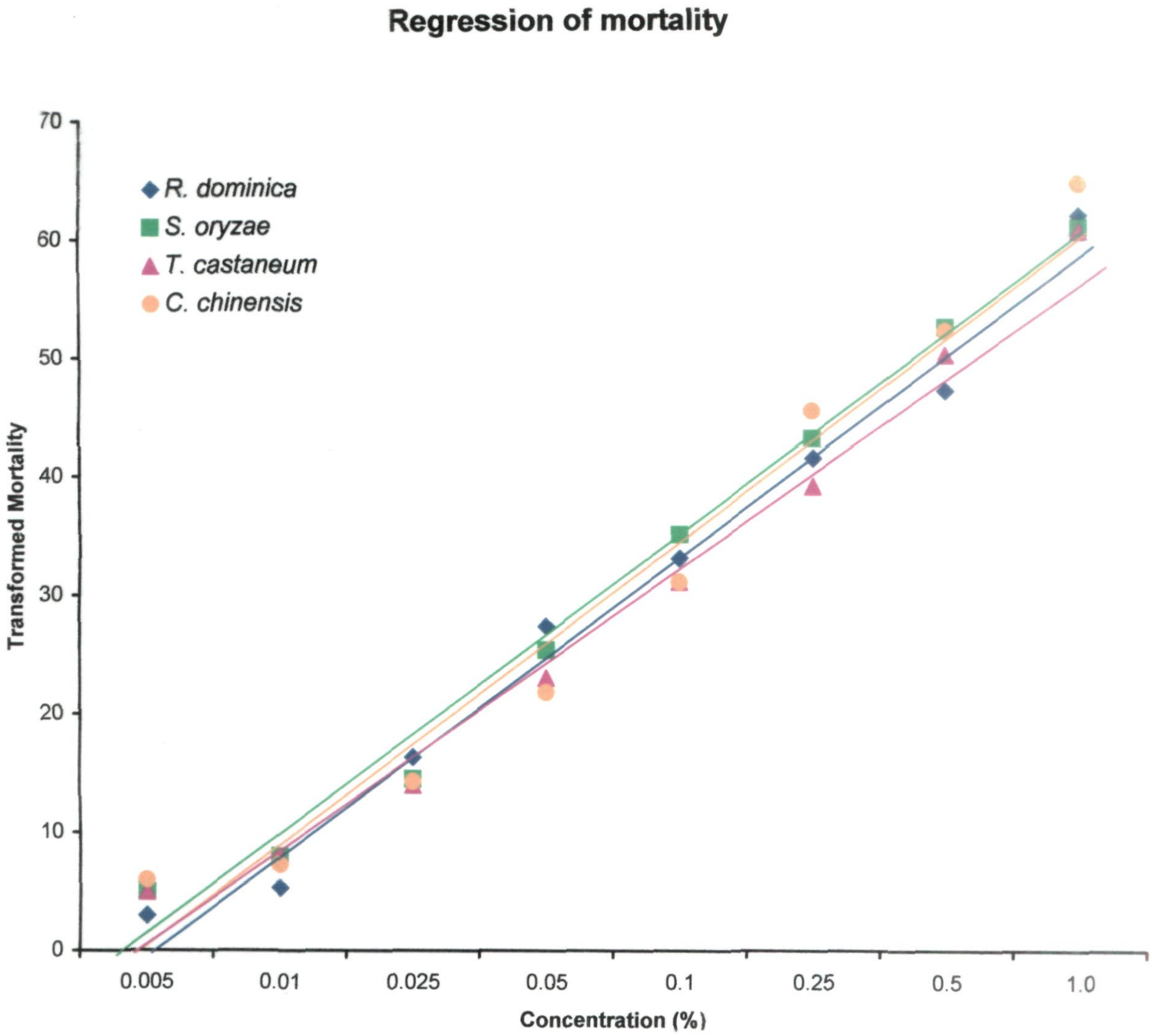

Fig. 31: Transformed mortality response (TMR) in terms of regression lines against *D. fastuosa* (leaf)

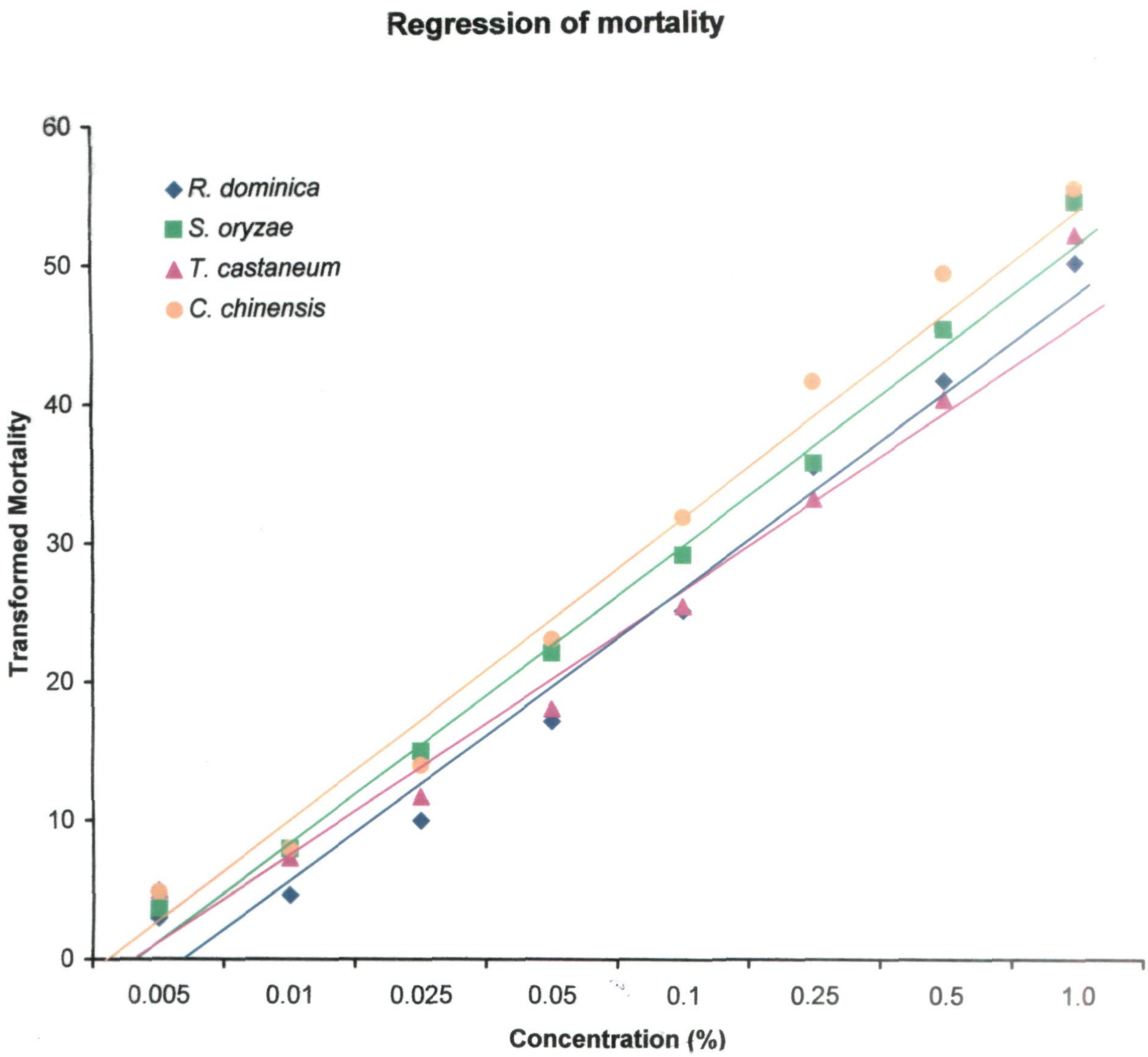

Fig. 32: Transformed mortality response (TMR) in terms of regression lines against *L. camara* (leaf)

Discussion

DISCUSSION

The control of insect pests is a goal which challenges every fibre of man ingenuity and intelligence for this purpose man has been devising new and newer methods, tools and techniques. However, every time insects find some way to blunt every weapon invented by man to exterminate them. Thus man's search for a master weapon to be used against nuisence insects in order to achieve desired victory still goes on.

At the storage stage, food grains are infested by several stored grain insect pests. Almost all the insect pests of stored grain have a remarkably high rate of multiplication and within one season they may destroy 20% of the grains and contaminate the rest with undesirable odour and flavours. One should always keep in mind high rate of multiplication and should search out not only for chemicals and botanicals which cause mortality, efforts should also be directed for feeding and reproduction deterring agents. Guides (1990) reported that insecticides have been widely used to protect grains from insect infestation.

The indiscriminate use of pesticides is causing alarm all over the world as it gives rise to resistance development. The perusal of literature shows that resistance and residual toxicity problem under the present condition of storage pest is very serious with respect to insecticides specially contact chemicals as they cause toxic residues, users safety hazards. The cost of insecticides also necessitates for the search of alternative methods of storage pest control (Narasaiah 1994). Jilani *et al.* (1988) reported that plant products with insecticidal properties are becoming an alternative to the synthetic, dangerous and more expensive insecticides used in developing countries. Botanicals which are traditionally used by the farmers in the developing countries appear to be quite safe and promising in pest control. Their activities are many fold and they induce fumigant and topical toxicity as well as antifeedent and repellent effects (Regnault–Roger 1997). Present day need is to identify active components of botanical materials used in grain protection (Hassanali *et al.* 1990; Weaver *et al.*, 1991). Casida (1990) reported that the effect of different plant materials on insects may depend on several factors such as chemical composition and species susceptibility.

In the present investigation comparative efficacies of five chemical insecticides *viz.* monocrotophos, methyl parathion, dimethoate, cypermethrin, chlorpyrifos and botanical insecticides *viz.* *Azadirachta indica* (seed), *A. indica* (leaf), *Datura fastuosa* (leaf), *Calotropis procera* (leaf) and *Lantana camara* (leaf) extracts are evaluated against four important stored grain pests namely; *Rhizopertha dominica Sitophilus oryzae, Tribolium castaneum* and

Callosobruchus chinensis to suggest safe methods of stored grain pest control. All the five chemical insecticides tested against the insect pests effectively reduced the survival rate while all the selected botanical insecticides, moderately affected the survival rate of four stored grain pests. On an average mortality rate increased with increase of concentration and vice–versa.

The rice weevil was found to be more susceptible to chemical insecticides than lesser grain borer. Same trend of results was recorded by Samson and Parker (1989), Arthur (1994). Results from this study indicated that both, higher rate of application and longer exposure interval will be required to give the same level of control for the lesser grain borer compared to the *Sitophilus oryzae*. In another study chlorpyrios–methyl treatment (30 ppm dust) resulted in 83.3–90% kill of *S. oryzae* and 100% mortality of *S. oryzae* was recorded up to 6 months (Quintan *et al.* 1979, Bengston 1988). During present study chlorpyrifos found to be most effective against *S. oryzae* and *C. chinensis*. Present results are in agreement with those given by Pathak & Jha (2001).

The findings of present investigation show that monocrotophos emerged to be most toxic against *S. oryzae* followed by *C. chinensis*, *R. dominica* and *T. castaneum* (LC_{50} = 0.0760, 0.0750, 0.0880, 0.0930 respectively). These findings are compatible with that of Singh and Saxena (1995) and Hasan *et al.* (1983). Monocrotophos

(LC_{50} 0.07986) was more toxic than cypermethrin (LC_{50} 0.0883) for *T. castaneum*. The present findings are in confirmity with Saxena & Sinha (1995).

Dimethcate resulted in 75–85% mortality against different stored grain pests which is in approximity with results given by Degi and Chaudhary (1998) and EL–Ghar *et al.* (1994). They applied dimethoate against *Mylabris* sp. and morality reached to 99.4%. The difference in mortality is due to insect species and mode of application of insecticide as in present study insecticides were applied through impregnated pellets. Dimethoate was found less effective than monocrotophos. Which gave 90.33% mortality against *T. castaneum*. The present findings are not in agreement with those given by Jha and Singh (1984) who found dimethoate more toxic then monocrotophos against *T. castaneum*.

Cypermethrin at 1% conc. resulted in 100%, 91%, 85.66% and 88% mortality against *C. chinensis, S. oryzae, R. dominica* & *T. castaneum* respectively. Same trend was observed by Razan and Chahal (1987) and Singh and Yadava (2001).

It is clearly evident from the present results that most of the biocides give promising results against four stored grain pests. *A. indica* (leaf) extract proved to be most toxic against *C. chinensis, S.*

oryzae, R. dominica and *T. castaneum* at 1% conc (with morality rates of 89.00%, 83.66%, 79.33%, 77.30% respectively).

It was followed by *A. indica* (seed) extract which gave 83.33% mortality to *C. chinensis*, 80.33% mortality to *S. oryzae*, 75% mortality to *R. dominica* and 73% mortality to *T. castaneum* at 1% conc after 48 hour exposure. These findings are in confirmation with the results obtained by Al–sarook *et al.* (1991) observed larvicidal activity of acetone extracts from *Melia yolkensi* and *Melia azaderach* seeds. Neem extract caused effective mortality effect in the five nymphal instars of the gregarious phase of locust species (Freisewinkel and Schmutterer 1991, Michol and Schmutterer 1991). Jotwani and Sircar (1965 and 1967) have reported the efficacy of need seed as a protectant against four important storage pests of wheat & pulses viz. *C. maculatus*, *T. granarium, R. dominica* and *S. oryzae.* These workers have successfully shown the repellent property of neem seed. Neem oil at 1% conc. gives protection to rice against *R. dominica* up to six months. Girish and Jain (1974) and Xie *et al.* (1995) reported the efficiency of neem kernel powder to protect rice pests and minimizing the storage losses. Present results are consistent with the reported findings. Jaipal *et al.* (1984) reported 85% reduction in *R. dominica* population by using neem leaf extract. While comparing efficacy of neem leaf extract with insecticides, the present results are contradictory to the findings of Imtiaz *et al.*

(1999). They found neem extract more toxic than cypermethrin and methyl parathion but present investigation indicates that neem extract is more or less equally toxic to methyl parathion but significantly less effective than cypermethrin.

Calotropis procera appeared to be most effective plant extract after neem leaf & seed extracts as per experimental results. The LC_{50} values were 0.2775 for *S. oryzae* and 0.4288 for *T. castaneum.* The present findings are in close confirmation with results given by Parveen *et al.* (1998) in case of *T. castaneum* but *C. procera* proved to be slightly more effective against *S. oryzae* as compare to *R. dominica* (Parveen *et al.* 1998). *R. dominica* was significantly less affected by *C. procera* and *A. indica* they resulted in 62.66% & 79.33% mortality against *R. dominica* as compare to *C. chinensis* against which *C. procera* caused 75.33 and *A. indica* caused 89.00% mortality, approximately same trend of results was reported by Jilani and Malik (1973).

In the present investigation it is also observed that *D. fastuosa* leaf extract has lethal effects on the four stored grain pests but it was less effective than *C. procera* which appeared to be most toxic to *C. chinensis* with 64.33% morality which was highest among all the insects Paswal *et al.* (1998). Yadav and Bhatnagar (1987) studied the lethal effects of datura, neem and ak leaf powders in protecting the stored cowpea seeds from *C. chinensis.*

The extracts of *L. camara* does not show strong lethal effects. Its efficacy to the four stored grain pests is found to be moderate *L. camara* resulted in 55% mortality of *C. chinensis* at 1% conc after 48 hour exposure. Results are not in agreement with Tripathi *et al.* (2001) who reported 75–80% mortality at 1% conc. of *L. camara* extract. Islam *et al.* (1989) observed 2% *L. camara* extract equally effective to 2.5 EC Deltamethrin. According to Pandey *et al.* (1977) *L. camara* posses 50% repellent, antifeedent and average insecticidal properties against the larvae of mustard saw fly *Athelia proxima* (Klung). The 1% conc. of *L. camara* (leaves) tested on *T. castaneum* gives survival rate of 31.25% as compared to 45.82% by *S. oryzae*. Pandey *et al.* (1986) reported that 0.5, 1.0, 1.5 conc were toxic to *C. chinensis* infesting green gram and checked oviposition up to 100% at 1.5% conc.

The results indicate that plant based compounds such as *Azadirachta indica* (leaf extract), *A. indica* (seed extract) and *C. procera* (leaf extract) can be suggested to be effective alternative to conventional synthetic insecticides for the control of stored product pests.

The most important work is to search out possible scientific rationale for the incorporation of these products in to grain protection practices. According to Chambers (1977), the feasibility of use of these materials under godown situation is still questionable due to difference in the physiological sensitivity between laboratory colony insects and godown populations. Thus, there is a need for more thorough investigation in to such practices to facilitate their improvement and adoption for the control of stored product Insect pests especially in rural communities. Plant derived toxicants are appearing to be invaluable source of potential biopesticides to enhance the grain protection alternatives. These products should be used within an IPM framework, as indiscriminate use will result in the same negative consequences as caused by extreme use of synthetic pesticides. The study of mode of action of these plant products is in Progress in our laboratory and will contribute to their use in future in stored grain protection programme.

Summary

SUMMARY

Food grains are produced in bulk so these can be stored for future consumption to fulfill nutritional requirements of human being. To attain the objective appropriate storage conditions are required. Insect pests are the major factors which contribute a considerable part towards the detoriation of stored food grains. During present investigation efforts are made to improve storage facilities. For such purpose comparative toxicity of five chemical insecticides and five botanical pesticides has been tested against four stored product insect pests namely *Rhizopertha dominica, Sitophilus oryzae, Tribolium castaneum* and *Callosobruchus chinensis.* Synthetic chemical insecticides *viz.* Monocrotophos methyl parathion, Cypermethrin, Dimetheote and Chlorpyrifos were procured from manufacturers. The botanical insecticides *viz. Azadirachta indica* (leaf extract), *Azadirachta indica* (seed extract), *Calotropis procera* (leaf extract), *Datura fastuosa* (leaf extract) and *Lantana camara* (leaf extract) were tested as petroleum ether extract. Efficacy of eight concentrations ranging from 0.005% to 1% are tested against four experimental stored grain pests. One day old adults of insect pests were allowed to feed on treated pellects. Experiments were carried out in laboratory at 28±2°C temperature and 75±5% RH observation were taken at every 24 hour interval.

It was further noted that among all the chemical insecticides, monocrotophos was proved to be most toxic against *Rhizopertha dominica* (LC_{50}=0.114). *Callosobruchus chinensis* (LC_{50}=0.176). *Sitophilus oryzae* (LC_{50}=0.171) and *Tribolium castanium* (LC_{50}=0.186).

It was that even low dosages of synthetic chemical insecticides are effective against four stored grain pests, so further more study is required to find out the best possible minimum dose and exposure time to attain the objective of minimization of indiscriminate use of chemical insecticides as their persistency and costs are high, therefore causes Mammalian toxicity.

The most productive part of the present study is that *A. indica* (leaf and seed extract) showed promising mortality effect over insect pest population. *A. indica* leaf extract caused 79.33% mortality of *Rhizopertha dominica,* 89.00% mortality of *Callosobruchus chinensis,* 83.66%. Mortality of *Sitophilus oryzae* and 77.33% mortality of *Tribolium castaneum*. *A. indica* (seed extract) was found a little less effective then *A. indica* leaf extract at 1% concentration at 48 hour exposure. Result obtained by use of *Calotropis procera* are quite satisfactory. *Datura fastuosa* and *Lantana camara* were found less effective. It is advisable to make farmers aware of the use of these biocides of plant origin since botanical pesticides are safer. Efforts should be made to minimize the use of chemical insecticides and this can be done by using insecticides of plant origin or by using mixed formulations of chemical insecticides and botanical pesticides. Further research is needed to find out the effective biochemical fractions of botanical insecticides, more screening should be done in order to find out other plant products which are effective against stored grain pests and to make their formulations available in the market.

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